NEW

BIGGEST FASTEST TALLEST LONGEST GREATEST

TOUGHEST QUAD BIKES

MASSIVE MONSTER TRUCKS

FANTASTIC FLYING MACHINES

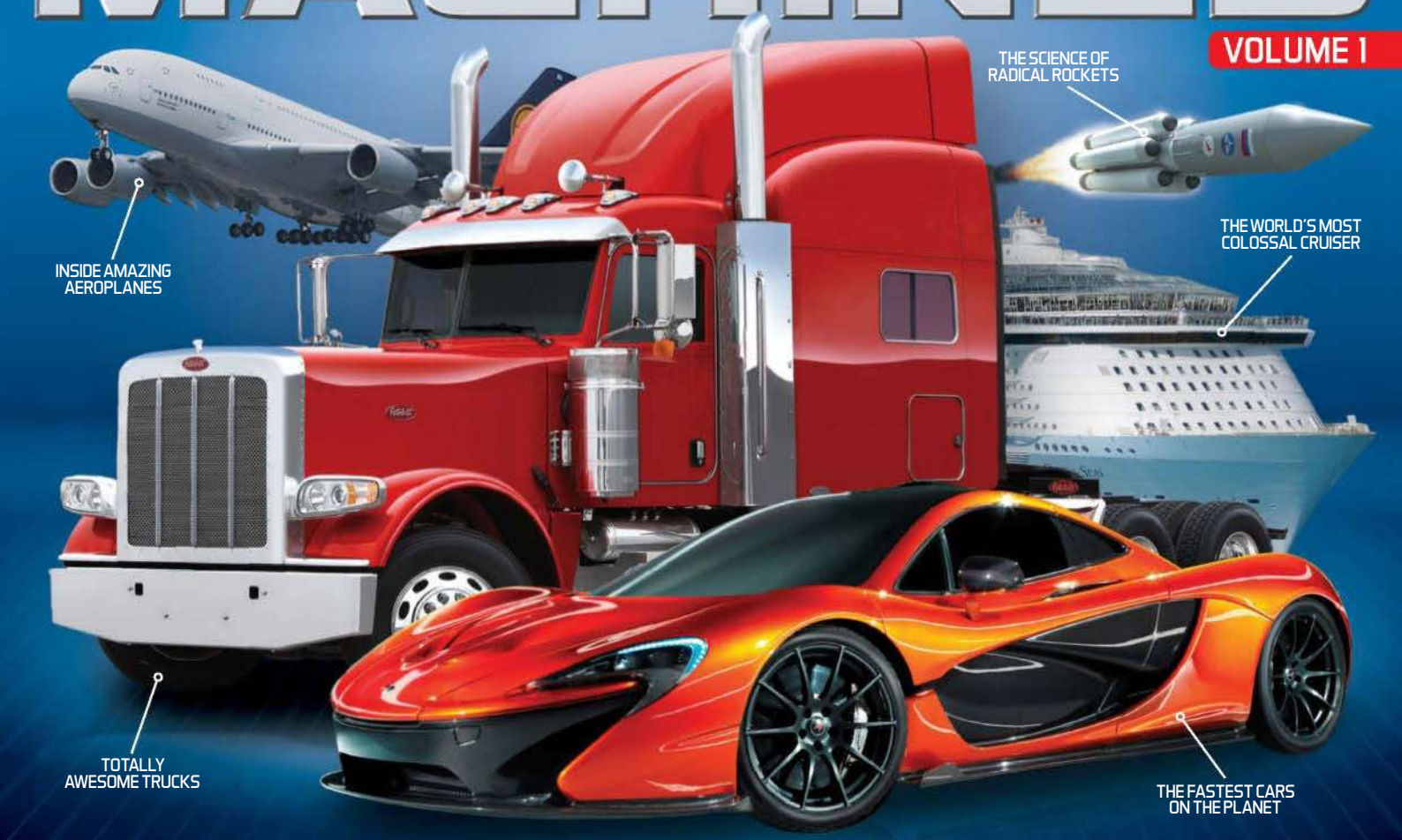
INCREDIBLE INNOVATIONS

HOW IT WORKS

BOOK OF

MEGA MACHINES

VOLUME 1



THE SCIENCE OF RADICAL ROCKETS

INSIDE AMAZING AEROPLANES

THE WORLD'S MOST COLOSSAL CRUISER

TOTALLY AWESOME TRUCKS

THE FASTEST CARS ON THE PLANET

A LOOK INSIDE SOME OF THE WORLD'S MOST INCREDIBLE MACHINES

HOW IT WORKS

BOOK OF

MEGA MACHINES

Whether they're trucks, cars, boats, planes or the huge haulers that carry goods around the world every day, machines are fascinating. There are some that are even more incredible than others – the biggest, fastest, longest, tallest, or just plain greatest in the world. Here, you'll find out all about these astonishing machines, and find answers to questions like 'how big is the world's tallest monster truck?' Discover the niftiest deep-sea exploration vehicles and see what the future of travel and transport holds. You'll find out all about the incredible technology that has helped humans to venture into space, as well as out-there inventions like drones and jet packs. Get ready for a ride through some of the world's most mega machines!

HOW IT WORKS BOOK OF MEGA MACHINES

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NEXT-GEN HYPERCARS

NEXT-GEN HYPERCARS

Just when you thought the world's fastest cars had reached the pinnacle of motoring physics, a new generation is set to break the boundaries once more

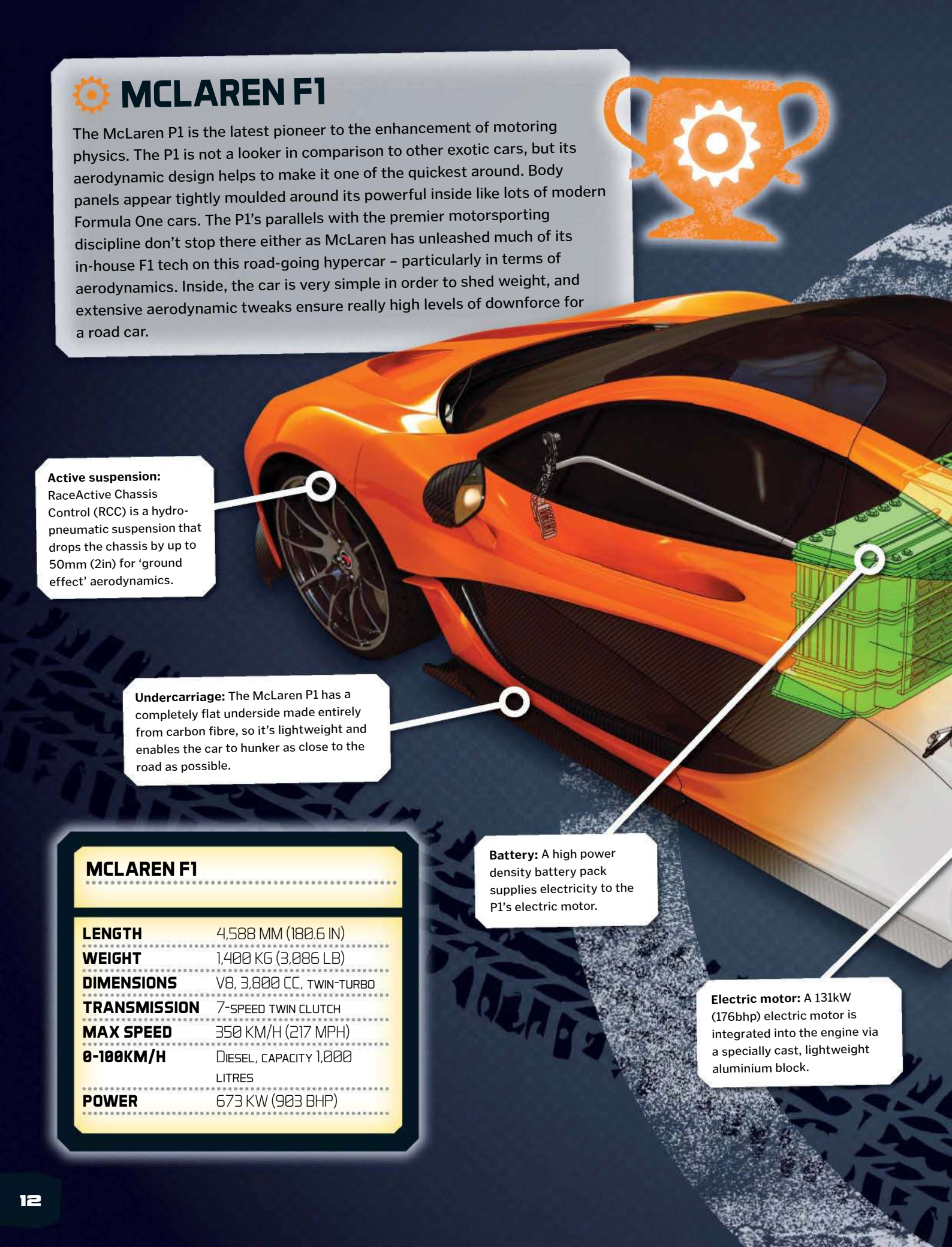
Today's hypercars are faster, lighter, safer, cleaner and more efficient than ever before, as they push physics to the limit to deliver the ultimate thrill behind the wheel.

The first car in the world to hit 322 kilometres (200 miles) per hour was a purpose-built land speed machine driven by Sir Henry Segrave at Daytona Beach, USA in 1927. Now, everyday road-going hypercars reach that figure easily, and some go way above that. Lightweight chassis and body panels are now used to help keep the overall weight of these cars at large to a minimum, greatly increasing a car's power-to-weight ratio – essential for extracting maximum power.


439km/h top speed.
Lowered centre of gravity.
V8 engine with hybrid module.

MCLAREN F1

The McLaren P1 is the latest pioneer to the enhancement of motoring physics. The P1 is not a looker in comparison to other exotic cars, but its aerodynamic design helps to make it one of the quickest around. Body panels appear tightly moulded around its powerful inside like lots of modern Formula One cars. The P1's parallels with the premier motorsporting discipline don't stop there either as McLaren has unleashed much of its in-house F1 tech on this road-going hypercar – particularly in terms of aerodynamics. Inside, the car is very simple in order to shed weight, and extensive aerodynamic tweaks ensure really high levels of downforce for a road car.



Active suspension: RaceActive Chassis Control (RCC) is a hydro-pneumatic suspension that drops the chassis by up to 50mm (2in) for 'ground effect' aerodynamics.

Undercarriage: The McLaren P1 has a completely flat underside made entirely from carbon fibre, so it's lightweight and enables the car to hunker as close to the road as possible.

Battery: A high power density battery pack supplies electricity to the P1's electric motor.

Electric motor: A 131kW (176bhp) electric motor is integrated into the engine via a specially cast, lightweight aluminium block.

MCLAREN F1

LENGTH	4,588 MM (180.6 IN)
WEIGHT	1,400 KG (3,086 LB)
DIMENSIONS	V8, 3,800 CC, TWIN-TURBO
TRANSMISSION	7-SPEED TWIN CLUTCH
MAX SPEED	350 KM/H (217 MPH)
0-100KM/H	DIESEL, CAPACITY 1,000 LITRES
POWER	673 KW (903 BHP)

The McLaren P1 powers from rest to 300km/h (186mph) in less than 17 seconds – a full five seconds quicker than the McLaren F1.

Engine: The petrol enginein the McLaren P1 is a monstrous 3.8l twin-turbo V8.

Body vents: As well as generating downforce and reducing drag, vents in the body also aid the cooling of the powertrain – essential to keep the car performing under immense stress.

Rear diffuser: Developers tested the XSR48 at speeds in excess of 100mph – in the most extreme sea conditions.

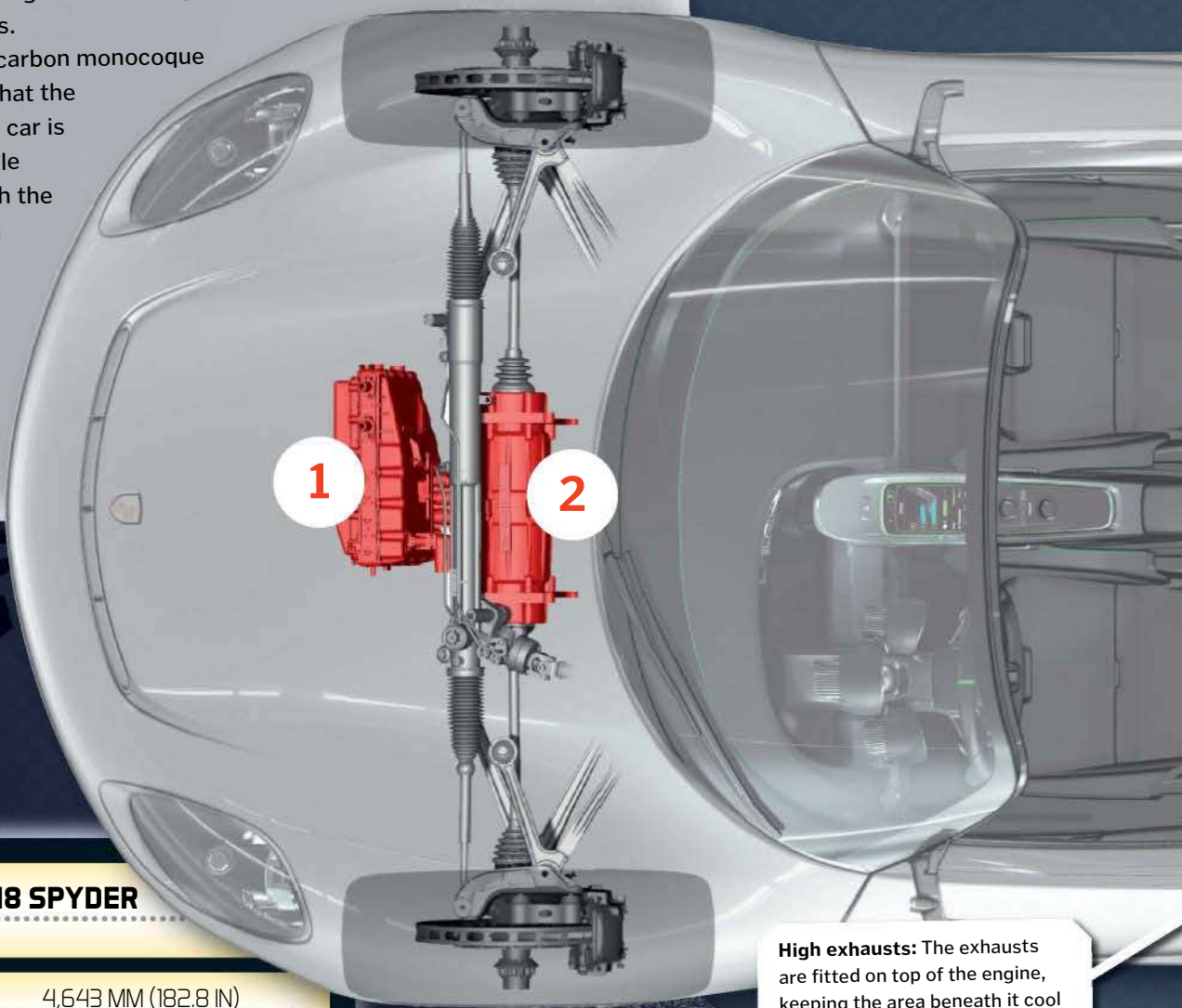
Active rear wing: A retractable active rear wing lifts by up to 30cm (11.8in) to maximise downforce, with the two-tier piece opening to activate the Drag Reduction System (DRS).

Gearbox: A dual-clutch, seven-speed gearbox makes for a reliably easy and smooth transition from speeds of 0-350km/h (0-217mph).

PORSCHE 918 SPYDER

Like the McLaren P1, the Porsche 918 Spyder uses lightweight efficiency along with brute power and aerodynamic refinement to get up to 322 kilometres (200 miles) per hour with ease. The drivetrain and other components weighing over 50 kilograms (110 pounds) in the plug-in hybrid are kept as low and central as possible to improve the centre of gravity and aid handling at speed. The exhaust pipes are also placed high up above the engine, for mechanical reasons rather than aerodynamics; the exhaust is occupying the already hot space above the engine, keeping the space underneath the engine cool enough to mount electric batteries.

Meanwhile, a carbon monocoque chassis means that the main part of the car is lightweight, while flaps underneath the headlights open to aid cooling of internal components and close at higher speeds to reduce drag.



High exhausts: The exhausts are fitted on top of the engine, keeping the area beneath it cool enough to store a useful low-mounted battery.

PORSCHE 918 SPYDER

LENGTH	4,643 MM (182.8 IN)
WEIGHT	1,700 KG (3,747 LB)
ENGINE	V8, 4,600 CC ENGINE WITH HYBRID MODULE
MAX SPEED	325 KM/H (202 MPH)
0-100KM/H	3.0SEC
0-100KM/H	593 KW (795 BHP)
POWER	673 KW (903 BHP)

1&7 Power electronics
2 Electric drive controller
3 Lithium-ion battery pack
4 V8 engine
5 Double-clutch gearbox
6 Electric motor

Porsche Active Suspension Management keeps the car rigid at high speeds.

Low gearbox: The 918's gearbox is flipped upside-down to reduce the centre of gravity, with the engine being positioned low down too.

Hybrid power: Two electric motors drive an axle each, working in conjunction with the V8 combustion engine.

Rear axle: Active rear axle steering makes cornering more direct and faster.

The low mounting position of the battery and powertrains ensures a low centre of gravity.

RIMAC CONCEPT ONE

Although many hypercars use hybrid technology to cut down emissions, the Rimac Concept One is the first to be fully electric, eliminating the boundaries set by combustion engines including rev limits and turbo lag. Instead of a traditional combustion engine, this car's powertrain is divided up into four electrical subsystems consisting of a motor, inverter and reduction gearbox, with each subsystem powering one wheel independently. Even better, the 92-kilowatt battery has a decent range too, powering the hypercar for up to 600 kilometres (373 miles) of driving with no environment-harming emissions.

FERRARI ENZO

Ferrari's new hypercar is effectively the 2013 equivalent of its last true hypercar, the 2003 Ferrari Enzo. Although LaFerrari retains the same overall length and wheelbase as the Enzo, key specification adjustments allow for this new model to go even faster.

LaFerrari is 43 millimetres (1.7 inches) narrower and 31 millimetres (1.2 inches) shorter than the Enzo to the floor, with a 35-millimetre (1.4-inch) lower centre of gravity and greater weight distribution to the rear (by a whole two per cent). This means the car can slip through the air quicker and better hug the ground around bends – both crucial ingredients for going fast. Ferrari is another high-performance brand keen to clean up its act, so LaFerrari has also employed hybrid technology in order to bring overall exhaust emissions down.

Tapered front: LaFerrari has a smaller point of contact with air at the front of the vehicle, reducing wind resistance.

Bumper vent: Large vents in the front bumper push air quickly underneath the car, enabling LaFerrari to stick to the road, even when travelling at high speed.

Wheels and tyres: The Enzo has 19-inch (483 mm) wheels. They are held by a single lug nut and fitted with Bridgestone Potenza Scuderia RE050A tires.

The DeltaWing is perfectly streamlined for speed.

NISSAN DELTAWING

Although not a commercial production car, Nissan's DeltaWing is a motoring phenomenon. The rip-roaring race car reaches 100 kilometres (62 miles) per hour in just 3.3 seconds and powers on to a top speed of 315 kilometres (196 miles) per hour – all from a modest four-cylinder, 1.9-litre turbocharged engine. Such excellent performance is delivered by well-thought-out physics.

First, the car's mass: the majority of the chassis and body panels on the DeltaWing are made from carbon fibre (a composite that is lighter than steel), aluminium and other materials. The DeltaWing weighs a mere 490 kilograms (1,080 pounds) so less power from the engine is needed to get the vehicle moving. The position of weight is also important: the rear engine, rear wheel drive layout, coupled with the narrow front and wide back end, means weight distribution is more towards the back than on most cars, with 72.5 per cent of the total mass between the wide back tyres.

Side vent: These assist with the cooling down of the engine to allow for the optimum performance.

KOENIGSEGG AGERA R

The Agera R can produce 850 kilowatts (1,140 horsepower) from its 5.0-litre, twin-turbocharged V8 powertrain. It has 48.3cm (19-inch) wheels; not only are they made from carbon fibre, but they're hollow-spoked too, saving 40 per cent over similar alloy wheels. While other hypercars manage downforce with an active rear wing that changes height according to speed, the Agera R changes its angle of wing to literally target downforce upon the rear.

The angle isn't determined by heavy hydraulics, but by the pressure of the wind. With the angle of the wing dictated by wind resistance, this compensates for headwind or tailwind at the same given speed. The Aero Exhaust is also shaped to improve air release.

The latest Koenigsegg has continued aerodynamic evolution and much greater speed.

SPEEDIEST SPORTS CAR

BUGATTI VEYRON

With a top speed of 432 km/h, the Bugatti Veyron Super Sport is the fastest street-legal car in the world. It's a beautiful luxury sports car that can go so fast it needs special features to prevent it from lifting off the road!

Jeremy Clarkson of the BBC programme Top Gear called the Veyron "The greatest car ever made and the greatest car we will ever see in our lifetime." The car can be legally driven at top speed only in countries with no maximum speed limit.

At speeds above 200 km/h, the back wing is also used as an air brake like those that help to slow aeroplanes.

GET READY FOR SPEED

The Veyron's everyday top speed (in 'handling mode') is 350 km/h. When it reaches 220 km/h, the car adapts automatically. Hydraulics lower the body to reduce the ground clearance to 9 cm and the wing and spoiler deploy. The wing provides 3,425 N of force to hold the car down on the road. If the driver turns on 'top speed mode', it can go even faster. The car checks that the driver and car are ready and safe, then the spoiler retracts, the front air diffusers shut and ground clearance drops to 6.5 cm.

GOING...

The Veyron has an 8-litre, quad-turbocharged, W16 cylinder engine. This is the equivalent of two V8 engines placed side-by-side. A V8 has eight cylinders arranged in pairs so that they make four v-shapes. The pistons of the cylinders all drive the same crankshaft. As the pistons move in sequence, they push against the crankshaft and make it turn.

BUGATTI VEYRON SUPER SPORT

WHEN	2005
HOW HEAVY	1,888 KG
TOP SPEED	432 KM/H
ACCELERATION	0-100 KM/H IN 2.5 SECONDS
COST	£2,000,000
POWER	736 KW
ENGINE	7,993 CC

At very high speeds, hydraulics lower the chassis to keep the car on the road – otherwise lift might make it take off.

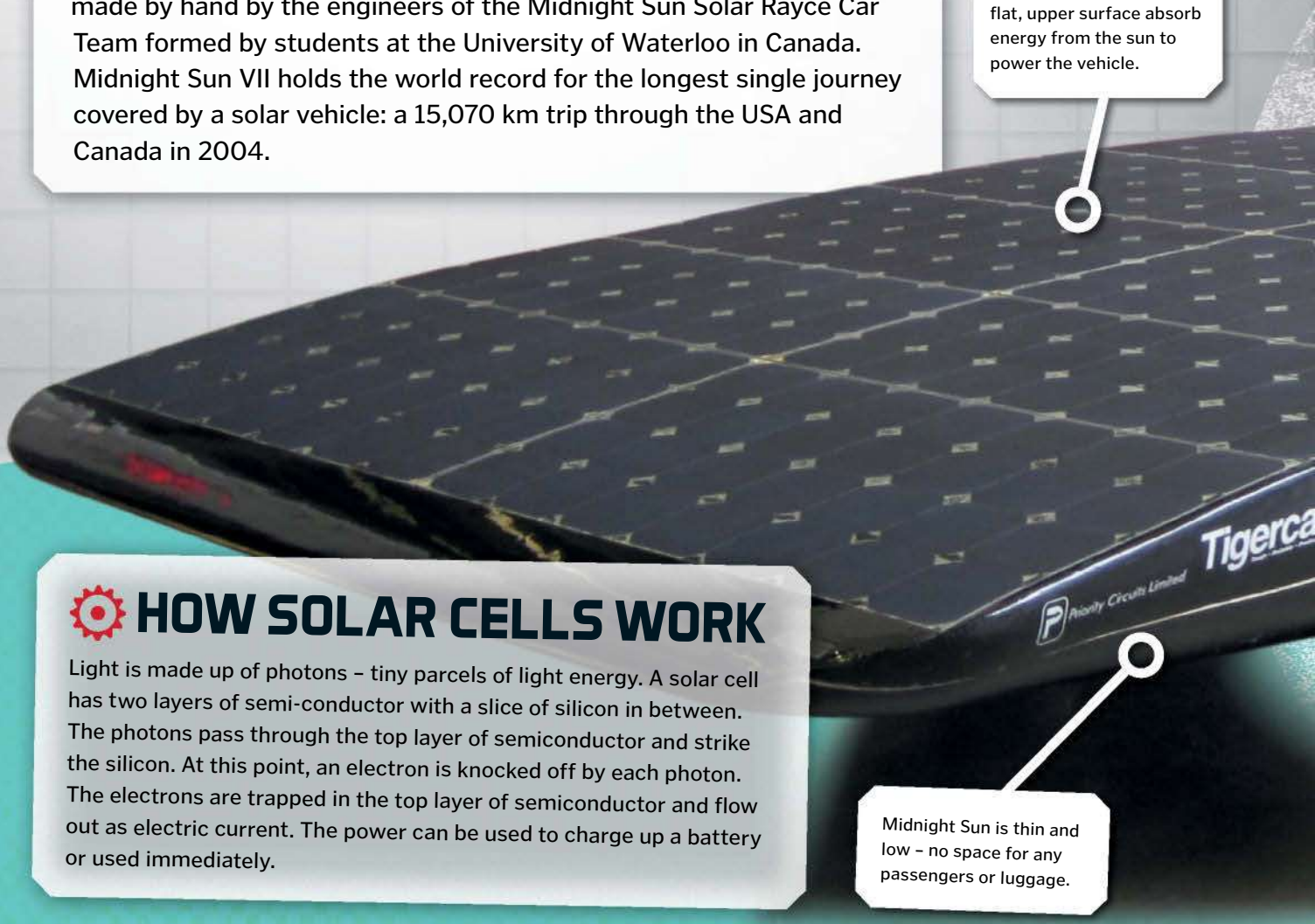
The W16 engine has four turbochargers. A turbocharger sucks air into the engine so that it can use fuel more quickly and generate more power.

FURTHEST TRAVELLING SOLAR CAR

MIDNIGHT SUN

Imagine a car that can run forever on no fuel - how cool would that be? The Midnight Sun solar car can do just that, as it takes all its energy from sunlight that falls on its flat upper surface.

Each Midnight Sun car takes about two years to make – they're all made by hand by the engineers of the Midnight Sun Solar Rayce Car Team formed by students at the University of Waterloo in Canada. Midnight Sun VII holds the world record for the longest single journey covered by a solar vehicle: a 15,070 km trip through the USA and Canada in 2004.



Solar panels on the large, flat, upper surface absorb energy from the sun to power the vehicle.

Midnight Sun is thin and low – no space for any passengers or luggage.

HOW SOLAR CELLS WORK

Light is made up of photons – tiny parcels of light energy. A solar cell has two layers of semi-conductor with a slice of silicon in between. The photons pass through the top layer of semiconductor and strike the silicon. At this point, an electron is knocked off by each photon. The electrons are trapped in the top layer of semiconductor and flow out as electric current. The power can be used to charge up a battery or used immediately.

MIDNIGHT SUN VII

WHEN	2004
HOW HEAVY	213 KG
TOP SPEED	130 KM/H
SIZE	1.5 M x 5.5 M

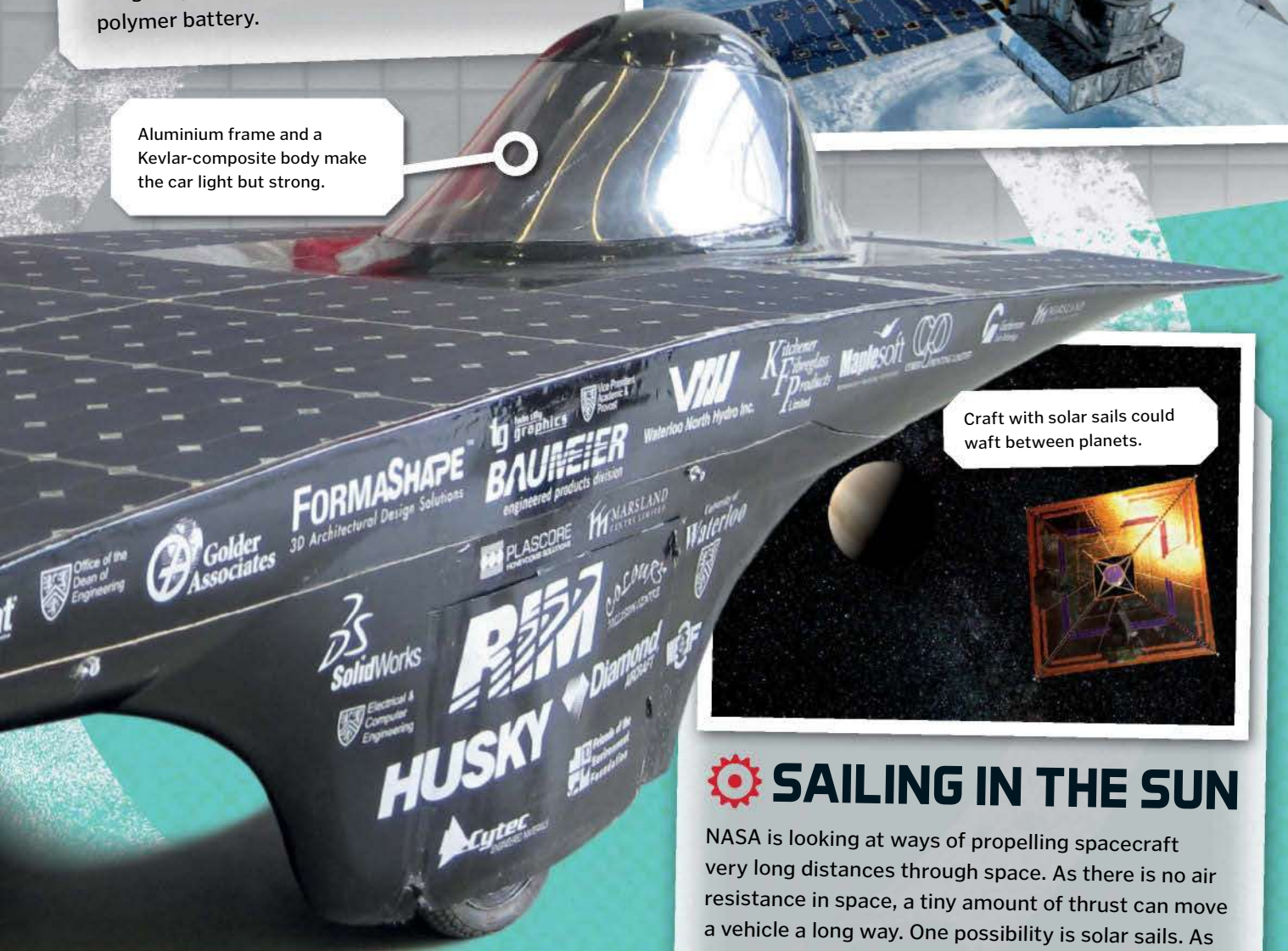
SUN IN SPACE

In space, sunlight is available all the time and is much stronger than on Earth. Satellites often use solar panels to provide the power they need to run electrical equipment. They can be angled to catch the most sunlight as the satellite moves through space.

CATCHING THE SUN

Midnight Sun X has 403 Sun Power A300 solar cells with a total sun-trapping area of 6m2. The energy caught by the solar cells is stored in a lithium polymer battery.

Aluminium frame and a Kevlar-composite body make the car light but strong.



Craft with solar sails could waft between planets.

SAILING IN THE SUN

NASA is looking at ways of propelling spacecraft very long distances through space. As there is no air resistance in space, a tiny amount of thrust can move a vehicle a long way. One possibility is solar sails. As photons fall on the sail, they push the vehicle through space, just like wind pushes a yacht over the water.

STRANGEST CUSTOM CARS

DODGE POWER WAGON

The world's biggest car is a scaled-up dodge power wagon built at a scale of 64:1. It belongs to Sheikh Hamad Al Nahyan of the united arab emirates.

The wheels of the Dodge are from an oil rig transporter and the wipers from an ocean liner. The headlights cost £1,000 each. It's equipped as a gigantic motorhome, with four bedrooms inside. It's so big that the pieces had to be taken out into the desert for assembly. The huge Dodge can be driven through empty desert but is too wide to use on a road.

The tailgate opens to form a balcony for the rooms inside the Dodge.

WORLD'S FASTEST SOFA

Sofas don't usually move – but this two-seater leather sofa can really shift. Fitted with a 1,400-cc Suzuki GSX motorcycle engine and an integral coffee table, the speedy sofa reached 163 km/h in 2011. The coffee table is not just a useful place for the fruit bowl – it breaks up the air flow and helps the sofa achieve its high speed.

The master bedroom is where the cab should be, and the driver has a smaller cab hidden away.

GIANT DODGE

HOW HEAVY	ABOUT 50 TONNES
SIZE	8 M WIDE
POWER	223.7 KW
ENGINE	GM DETROIT DIESEL 67

Every detail of the Dodge has been copied from a normal Dodge but sized up to make the monster vehicle eight times normal size.

CRAZY CARS

Custom cars are pimped-up cars that often look wacky on the outside and have surprisingly powerful engines hidden inside.

This VW Bus Ball has a door and driving seat but not wheels.

SAFEST CAR

VOLVO V40

The safest car in the world is the Volvo V40. Cars are crash-tested by... being crashed. All kinds of high-speed collisions are simulated in crash-test centres, and the damage to the car and fake occupants - crash-test dummies - is carefully measured.

With two adult dummies in the front and two child-sized dummies in the back, the Volvo V40 was driven into a pile of crash blocks at 64 km/h. The front of the car was mashed up – but the 'driver' and 'passengers' were protected by crumple zones, airbags and seat belts. The computer analysis showed they had no significant risk of injury.

The car is marked up with stickers. Comparing the relative positions of the stickers before and after he crash shows how much the metal has distorted.

CAREFUL CAR

The Volvo V40 has some very special safety features. The pedestrian-detection system can spot a person stepping into the road and warn the driver. If the driver doesn't respond, the car brakes automatically. And if a pedestrian is struck, the bonnet opens and an airbag protects the pedestrian.

The V40 on the road.

VOLVO V40

WHEN	2012
TOP SPEED	250 KM/H
ACCELERATION	0-100 KM/H IN 6.7 SECONDS
SIZE	4.37 M LONG
POWER	132 KW
ENGINE	TURBO-CHARGED T4 1.6 LITRE PETROL ENGINE (T4 MODEL)

TESTING, TESTING

Test cars are crashed in different ways, simulating the car crashing into something in front of it, being struck from behind and the sides and rolling over. Cameras film the car from all angles, both inside and outside the vehicle. Slowing down the footage recorded enables engineers to see exactly what happens in a crash test.

The rigid body does not give way under impact, except for special crumple zones that absorb the shock.

Airbags inflate on impact to protect driver and passengers, including extra airbags at the sides of the car and near the driver's legs. An external airbag protects any pedestrian struck by the car.

DUMMY!

The aim of making a car safe is to protect the people in it and, as far as possible, pedestrians on the road. Crash-test centres use dummies the same weight, size and shape as humans, and their body parts have the same weight distribution. They are fitted with monitors and sensors to collect data about forces operating on them during the impact.

SMALLEST CAR

PEEL P50

The tiniest production car ever made was the Peel P50. This three-wheeled microcar was made by Peel Engineering Company on the Isle of Man in 1962-65.

With its four-stroke 49 cc petrol engine mounted in the side, the P50 could manage 60 km/h. It had no starter motor and the driver had to use a crank handle to get it going. The P50 could be parked in a small space, but with no reverse gear it was often easier to get out and move it by hand. Just 50 P50s were made – 27 still exist.

Single headlight, single windscreen-wiper and just one door – it had room for 'one adult and a shopping bag'.

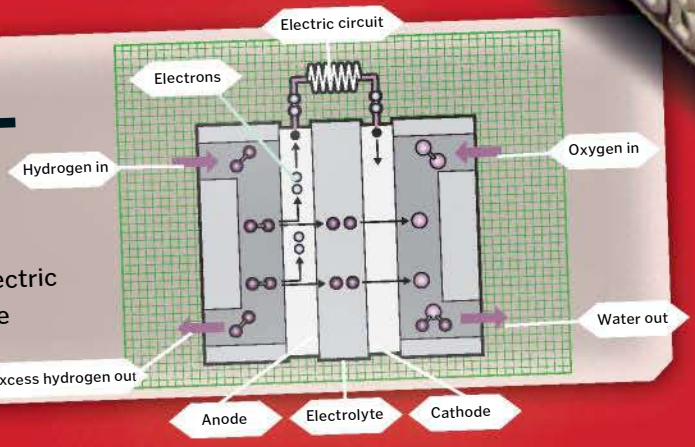
POSTMAN PAT REVAMPED

The smallest ever drivable car is the Wind-Up, made by British engineer Perry Watkins in 2009. It's made from a converted Postman Pat coin-in-the-slot ride and is 132 cm long, 104 cm tall and 66 cm wide. The fibreglass body is reinforced with a steel frame and there's a mini quad-bike with a 150 cc engine underneath.

HYDROGEN FUEL CELL

A hydrogen fuel cell is rather like a battery except that it never runs out.

Hydrogen enters the cell, where it breaks down to make electrons and hydrogen ions. The electrons produce the electric power and the hydrogen ions combine with oxygen to make water, which is the only waste product.



Fibreglass body available in red, white or blue.

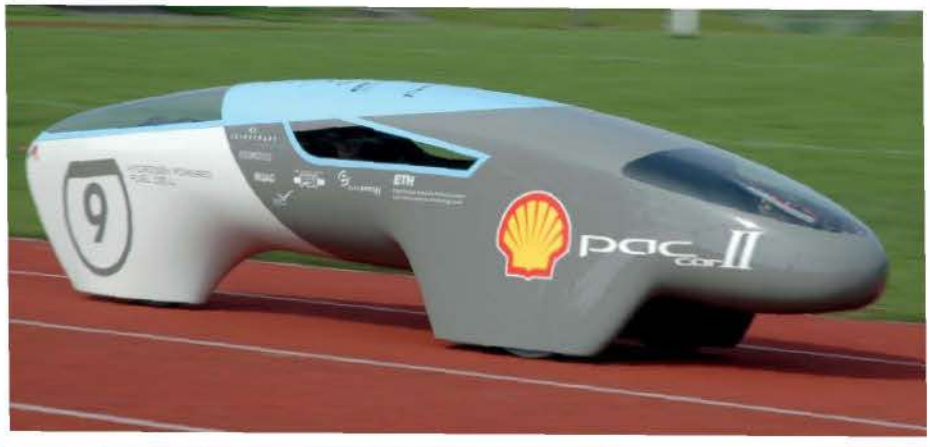
PEEL P50

HOW HEAVY	59 KG
TOP SPEED	60 KM/H
POWER	2.5 KW
ENGINE	49 CC

A handle on the rear made it easy to drag the car around, or it could be pulled by the front bumper.

SMALL AND EFFICIENT

The most fuel efficient car is the experimental PAC-Car II. Running on a hydrogen fuel cell, it uses only 1 g of hydrogen per 100 km. That's equivalent to 5,385 km per litre! The PAC-Car II could go three times round the world on the petrol Concorde used on the runway before take-off.



FIRST FLYING CAR

TERRAFUGIA TRANSITION

Have you ever wanted a flying car? This is it! The Terrafugia Transition is a car-plane - it can fly like a car, then fold away its wings on landing and drive along the road just like a normal car.

When the Terrafugia switches between car and plane modes, the engine changes from driving the wheels to driving a push propeller at the rear of the plane. It's equipped with an airframe parachute – a parchute that supports the whole plane if there is a failure.

The PAL-V's rotors fold out of the way for road driving.

WHIRLY-CAR

The PAL-V One is a cross between a car, a motorbike and a gyrocopter. Its blades, propellor and tail all fold away to create an odd-looking three-wheeled vehicle that can drive on any road. Powered by a 160-kW aircraft engine, it can reach 180 km/h both on land and in the air. It's designed to fly at under 1,200 m to avoid competing for airspace with commercial flights.

The cockpit has a light polycarbonate windscreen and windows to resist bird-strikes when flying, and modified airbags for safety on the road.

PARACHUTING CAR

The Parajet Skycar (in development) will combine a buggy-style road vehicle with a parachute. Driven by a 104-kW rotary engine, it can take off from a 200 m run of road or runway. It can fly at a maximum altitude of 4 km above sea level. On land, it's road legal but can also plough through sand and over rough terrain, with a top speed of 225 km/h.

The Skycar uses a custom-made paraglider wing.

GYROCOPTER OR HELICOPTER?

A helicopter has a powered rotor on the top. If the engine fails, the rotor stops. A gyrocopter has a powered propellor at the rear but the rotor blades are turned by moving air. If the engine fails, the gyro-blades keep turning and the craft can glide to Earth.

Electro-mechanical folding of the wings takes only 90 seconds and is triggered by a button inside the car/plane.

The wings fold at two points – upwards near the body and downwards mid-wing – so that they stow neatly.

TERRAFUGIA TRANSITION

WHEN	NOT YET RELEASED
HOW HEAVY (KG)	440
TOP SPEED (KPH)	185 KM/H IN AIR; 110 KM/H ON THE ROAD
FUEL CONSUMPTION	11 LITRES/100 KM (FLYING) 6.7 LITRES/100 KM (ON ROAD)
SIZE	8 M WINGSPAN; 2.3 M WIDE WITH WINGS FOLDED; 6 M LONG
COST	$279,000
POWER	75 KW
ENGINE	ROTAX 912ULS

MOST POPULAR CAR

VOLKSWAGEN BEETLE

The best-selling car of all time is the Volkswagen Beetle: more than 21 million have been built in the past 65 years.

The Beetle was invented as a car for the people – 'volkswagen' means 'people's car'. In 1933, the German government asked Porsche to develop an affordable car that could carry two adults and three children at 100 km/h. The Second World War started while they were still making prototypes and the first production Beetles were not made until 1946.

The engine is at the back, in the boot, and the car has rear-wheel drive – an unusual combination when the car was first designed.

FIRST MASS-PRODUCED CAR

The first truly affordable car was the Model T Ford: 15 million were built in the USA from 1908 to 1927. It was the first car to be made on a production line, each worker carrying out only one task. Cars could be built very quickly – one was finished every 15 minutes. The Model T had a 2,900-cc engine that produced 15 kW and could reach a top speed of 64–72 km/h. The earliest models were started with a crank handle.

VOLKSWAGEN BEETLE

WHEN	1946
TOP SPEED	100 KM/H
POWER	19 KW
ENGINE	995 CC

DESIGNED AND REDESIGNED

The Beetle has been through several redesigns and has been built in lots of countries besides Germany. But it still has a distinctive humped shape and an engine in the rear boot. A new soft-top convertible launched in 2013 – but the first soft-top was issued in 1949.

Beetles were built in Mexico from 1939-2003.

The original Beetle was nearly airtight and could float on water for a few minutes.

"ANY COLOUR AS LONG AS IT'S BLACK."

The Model T Ford was available only in black until 1926 – because the only type of paint that would dry quickly enough to use on the production line was a black lacquer called 'Japan black'. When better paints were invented, other colours became available.

MOST LUXURIOUS MOTORHOME

ELEMMENT PALAZZO

The amazing Marchi Mobile eleMMent Palazzo is the most luxurious production motorhome ever made.

The sumptuous insides include a kitchen, lounge area with a metre-wide flat-screen satellite TV and en-suite bedroom. There's a pop-up roof terrace, underfloor heating and a space-age driver's cockpit. There's even remote video access to show it off and remote control to turn on the heating and lighting before you get home.

At the press of a button, the side moves outwards to give 80% more floor space – and there's even a pop-up roof terrace called the 'sky lounge'.

MOTORHOME ON THE WATER

The Terra Wind is an amphibious motorhome – it can go on the land or in the water. It weighs 15,875 kg and is nearly 13 m long. Powered by a 246 kW Caterpillar diesel engine, it can go at 137 km/h on land, or 7 knots on water. It can handle waves up to nearly a metre high and winds up to 64 km/h. The inside is luxurious, with TVs, DVD and a surround-sound system, whirlpool bath tub and a swimming deck.

The Terra Wind is the world's first amphibious coach.

MARCHI MOBILE ELEMMENT PALAZZO

HOW HEAVY	20 TONNES
TOP SPEED	150 KM/H
FUEL CONSUMPTION	5.5 KM/LITRE
SIZE	12 M LONG
COST	$3,000,000
POWER	395 KW

It combines features from lots of luxury vehicles, with the rear diffuser of a sports car, the gangway of a business jet and the flybridge of a motor yacht.

The space-age aerodynamic design reduces fuel consumption by 20% and the glow-in-the-dark paint detailing makes it really stand out – even in the dark.

MOST RUGGED QUAD BIKE

YAMAHA RAPTOR 700R

Yamaha Raptor 700R quad bikes have won four Dakar Rallies - the longest annual rally in the world over almost 10,000 km of harsh terrain.

Quad bikes, or all-terrain vehicles (ATVs), are a cross between a motorbike and a car. They have four wheels like a car, but a single rider, handlebars and no roof or crash bar. They're designed for rough terrain, and extreme quad-bike rallies run over deserts, mud, hills or ice and snow.

BIG BEAST OF A BIKE

The biggest quad bike in the world is the Can Am Outlander 1000. With a 976-cc engine that can produce 60.3 kW and suspension that allows a lot of movement, it can power through the most terrible conditions. The airbox is high on the chassis to avoid sucking in too much water, mud and sand, and it filters the air before sending it to the engine. Engine braking helps slow the bike going downhill so it doesn't hurtle out of control.

Up to 25 cm wheel-travel deals with bumps and hollows.

Steel and aluminium chassis for a super-strong structure.

UP AND OVER

If hammering through mud isn't good enough, quad bikes can also be used for jumping. The longest ramp jump on a quad bike was 53.92 m, a record set in Australia in 2008 by American Jon Guetter.

686-cc four-stroke engine is optimised for torque – turning force – to make the Raptor stable and easy to manoeuvre.

YAMAHA RAPTOR 700R

WHEN	2006-12
HOW HEAVY	191 KG
ENGINE	686-CC FOUR-STROKE

TORQUE

Torque is a measure of rotational force. The torque determines the force with which the wheels of a vehicle can be turned, while the energy the engine can generate (in kW) is a measure of its power. A challenge for vehicles that run over difficult terrain is to turn the wheels with enough force to go up steep slopes and over uneven ground. A quad bike needs high torque at low rpm (revolutions per minute – how fast the engine turns) as it's not aiming to go fast but to stick to the ground.

NIFTIEST MOTORBIKE

UNO

We usually think of motorbikes as big, powerful monsters - but some are small and nifty. The Uno looks like only half of a motorbike! It's powered by an electric motor, run by a battery recharged from the mains, making it quiet, non-polluting, and cheap to run.

The Uno III version has an additional small wheel that can come down, and the two large wheels can be moved closer together, converting it into a normal motorcycle. The bike can even switch between modes while in use. The inventor calls it 'the first real Transformer'.

FOLDING MOTORBIKE

The Yike Bike transforms even more than the Uno – it's a motorbike with a big front wheel and a tiny back wheel. But that strange shape folds away into a compact package that can be carried in the boot of a car or on a train. The Yike is powered by an electric engine, and with a single battery pack, it can travel 10 km between charges. Its top speed is 23kph.

A strong, light carbon-fibre and aluminium frame makes the Yike portable.

MINI MOTOS

Mini motos are tiny. Most have a two-stroke engine with a capacity of 39-50 cc. They're only about 50 cm high and a metre long. The smallest can reach speeds of 40 km/h, but they're not legal for road use.

A short body makes the bike easy to manoeuvre and gives it a tight turning circle.

Uses gyro-technology for speed control: leaning forward accelerates and leaning back slows it down

Two narrow wheels look from the side like a single wheel!

UNO

WHEN	2008
HOW FAST	40 KM/H
HOW HEAVY	58 KG
FUEL CONSUMPTION	ABOUT 50 KM ON 3-4 HOURS' CHARGE
ENGINE	ELECTRIC

SMARTEST BIKE

FACTOR 001

A bicycle is a finely-tuned machine that works best if it is very light and aerodynamic and has parts that run smoothly and efficiently. But some bikes are smarter than others.

The Factor 001 has GPS and integrated hydraulic, electronic and lighting systems. It can work out the rider's body temperature and heartbeat and even how hard each leg is working. Each Factor 001 is custom-made and takes six engineers a week to make.

FASTEST BIKES

One of the fastest bikes has to be the Lotus 108 ridden by Chris Boardman in the 1992 Olympics in Barcelona. He covered 4 km in just over four minutes – an average speed of nearly 60 km/h. The bike has a solid back wheel, a three-spoke front wheel and very low handlebars to give the bike and rider an aerodynamic shape.

Fast bike, fast rider: Chris Boardman in 1992.

FACTOR 001

WHEN	2009
HOW FAST	113 KM/H
MADE BY	BERU F1 SYSTEMS
HOW HEAVY	7 KG
COST	£22,000

A carbon-fibre monocoque frame – a thin, curved, hollow shell – makes the bike super-strong and very light.

Hydraulic braking system with ceramic brakes.

Needle-thin wheels with untreaded tyres for grip and minimal friction.

PARALYMPIC CYCLING

Special designs for cyclists with disabilities can be powered using the arms instead of the legs. Sometimes the bikes have three wheels for stability. One way of powering bikes like this is for the cyclist to pull on cables. It takes as much strength as riding a regular bike.

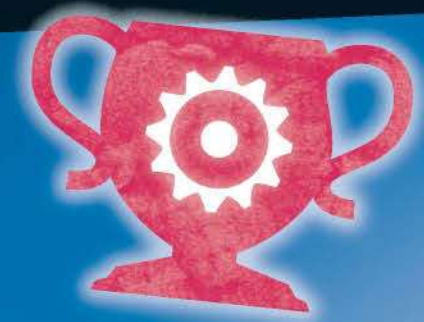
YOU-POWERED

We don't think of bicycles as machines, but they are. Instead of being powered by petrol or diesel, they're powered by people! The fuel for your bicycle is the food you have eaten, converted to energy in your muscles. An Olympic track cyclist can generate almost 3 kW.

HOW IT WORKS

MEGA GIANTS

HOW IT WORKS BOOK OF MEGA MACHINES




58
72
60

THE WORLD'S BIGGEST VEHICLES

HUGE HAULERS

These goliath machines are designed for maximum muscle power and maximum efficiency, but how do they work?

Believe it or not, the engineers, inventors and manufacturers who dream up the world's most gargantuan vehicles aren't in the business of glory hunting and collecting world records. In all cases, they are actually responding to an engineering challenge: whether it's how to shift millions of tons of mining debris, how to transport shipping containers using the least amount of fuel, or how to deploy tanks and troops into hostile territory with speed and stealth.

Some mammoth machines are built to serve a single role, like the crawler transporters employed by NASA to move super-heavy rocket technology. Or the Antonov An-225 – the world's largest aeroplane – designed to transport another huge vessel: Russia's Buran space shuttle.

TRACKED TITAN

There are 6.8 kilometres (4.2 miles) of road between the Vehicle Assembly Building and Launch Pad 39B at the Kennedy Space Center in Florida. A pair of goliath crawler transporters (CTs) carry NASA's rockets. The CT takes six hours to make a one-way trip. The pair of CTs was designed by a coal-mining company in the Sixties and were built to last – both still have their original engines: twin 2,050-kilowatt (2,750-horsepower) diesel beasts.

NASA's pair of crawler transporters recently received new ball bearings, ensuring 50 more years of service.

Rather than using a rear cargo ramp, the nose of the An-225 pivots upward at a 90-degree angle.

WINGED JUGGERNAUT

The Antonov An-225 Mriya is the world's biggest aircraft. Nearly the length of a football pitch, the first and only An-225 was finished in 1988 and is still in service. With a maximum flying weight of 640 tons, the An-225 has hauled several record-breaking loads, including the heaviest single piece of cargo – a 187-ton generator for a gas power plant – and the world's longest pieces of cargo – a pair of wind turbine blades measuring 42 metres (137 feet). This aircraft also has massive landing gear with 32 individual wheels.

MAERSK TRIPLE E

LENGTH	400 M (1,312 FT)
WIDTH	59 M (193 FT)
HEIGHT	73 M (240 FT) ABOVE BASELINE
DEADWEIGHT	165,000 TONS

The slow-moving Triple E can move 18,000 containers across the world.

MEGA CHOPPER

The Russian-made Mil Mi-26 is the largest of the 'heavycopters' – high-altitude, high-capacity helicopters that can easily transport up to 90 troops and heavy machinery to places that no plane or train can get access to. The Mi-26 is powered by its twin 8,500-kilowatt (11,400-horsepower) turbines that both share the load of driving a massive eight-bladed rotor. If one engine fails, the other can keep the chopper flying at full speed.

The Mi-26 is listed with a maximum service altitude of 4,600 metres (15,091 feet) and a maximum payload weight of 20,000 kilograms (44,092 pounds). Although initially used exclusively for military purposes, there are now more than 300 Mi-26 helicopters in service around the world, transporting heavy earth-moving equipment to flood zones.

The Mi-26 can rescue aircraft that have been stranded in aerial fights.

It was the first helicopter to come with an eight-blade main lift rotor.

MIL MI-26

LENGTH	40 M (131 FT)
ROTOR DIAMETER	32 M (105 FT)
HEIGHT	8.1 M (26.6 FT)
WEIGHT	28,200 KG (62,170 LB)

This super-sub is loaded with 20 missiles with nuclear warheads.

TYPHOON SUB

The Typhoon-class submarine is the largest of the Soviet Union's nuclear fleet. The Typhoon, nicknamed Akula (Shark), is a nuclear sub in two ways: first, its steam turbines are powered by an on-board nuclear water reactor; and second, it carries a payload of up to 20 ballistic missiles, each equipped with ten nuclear warheads. Despite its size, the Typhoon is very quiet, aided by an innovative multi-hulled design and sound-dampening exterior tiles. The Typhoon was built to conduct long missions under thick layers of Arctic ice; indeed, it can remain submerged for up to 120 days and the blade-like sail makes for an effective ice-breaker. Only six Typhoon-class subs were ever built and the last two were scheduled for decommission in 2014.

The Russian helicopter is the largest ever to have been produced.

LARGEST LAUNCHER

It's hard to imagine the size of the Saturn V, standing 18 metres (60 feet) taller than the Statue of Liberty. The Apollo astronauts in their tiny capsule were essentially strapped to a tower of rocket fuel. At launch, the first stage of the three-stage Saturn V generated 34.5 million Newtons (7.6 million pounds-force) of thrust, burning 2.1 million kilograms (4.7 million pounds) of propellant in less than three minutes. At 68 kilometres (42 miles), the first stage detached and the second stage ignited, thrusting the rocket into near orbit. The third stage burned for two minutes, putting the capsule into 'parking orbit' 190 kilometres (118 miles) into space.

The Saturn V weighed 400-plus elephants, but packed enough power to carry 43,500 kilograms (95,900 pounds) of cargo to the Moon.

TALLEST MONSTER TRUCK

BIGFOOT 5

Monster trucks are modified pickup trucks with custom suspension systems and giant wheels recycled from much larger vehicles. The Bigfoot 5 monster truck stands almost 5 m tall and was built specially to use its gigantic, ex-Army tyres.

Bigfoot 5 was first used for crushing cars in a publicity stunt. That attracted attention and more monster trucks followed. Now, monster trucks are often used for racing round obstacle courses, drag racing and mud driving as well as stunts.

Front and rear steering, with the rear steering driven by hydraulic pumps.

Eight 3-metre Firestone Tundra tyres weigh 1,088 kg each and were previously used on a US Army land train in Alaska.

Two truck frames make up the chassis that supports a modified body of a pickup truck.

BIGFOOT 5

WHEN	1986
HOW HEAVY	12,700 KG
SIZE	5 M TALL
ENGINE	7.5 LITRE PETROL ENGINE

MONSTER DUMPER

The largest real dumper truck is the Liebherr T 282B. It's too big and heavy to drive on public roads, and is shipped in parts and built on site. It has a 90-litre diesel engine capable of generating 2,720 kW. The T 282B can haul a load of 363,000 kg and is used mostly in gold, copper, iron and coal mines in the USA, Chile, South Africa and Australia. Each truck costs around $5 million.

ALL CHANGE!

Most modern monster trucks have fibreglass body panels, which are easy and cheap to repair and much lighter than sheet metal. It's easy to switch fibreglass bodies quickly to change the identity of a truck. The body is a shell that covers the rest of the truck. It's sometimes moulded with a special customized design.

RUNNING AND JUMPING

Racing monster trucks often have the tyres shaved using special tools. Doing this, teams can create their own tread patterns, but can also cut the weight of the vehicle – they remove up to 90 kg from each tyre. In 1999, Bigfoot 14 made the longest monster truck jump ever, covering 61.6 m and clearing a Boeing 727 jetliner.

Monster trucks need good suspension to deal with jolts.

LARGEST LIMO

MIDNIGHT RIDER

The largest limo in the world is the Midnight Rider, a tractor-trailer limousine pimped to perfection.

As well as three downstairs lounges decorated with brass and polished wood, there's a bronze staircase up to an observation lounge. Midnight Rider has a full bar, four landline phone connections, climate control heating and air conditioning – and a security monitoring system. With its own generators, all the electrical equipment works when the engine is not running.

MIDNIGHT RIDER

HOW HEAVY	22,934 KG
SIZE	21.33 M LONG
POWER	324 KW

BIG, BUT SMALL

It sounds crazy but there are even limos made from Minis. Minis are small and limos are big, but by adding enough extra space to the middle of a Mini, it can be turned into a limo.

The American Dream limo is an amazing 30.5 m long.

LONGEST LIMO

The longest limo in the world is the American Dream. Inside, it has a jacuzzi, a swimming pool with a diving board, a double bed and a satellite dish. Outside, there's a helipad and a sun deck. It has driver's compartments front and rear – the rear one is used for reversing. It's not street legal, so it's transported to events on two trucks and joined back together at the destination.

Seats 40 passengers in three lounges, each equipped with large satellite TV screens and entertainment systems, movies, music and live feeds.

SWANKY!

Limousines are usually made by extending a car and fitting it out with extra seats and lots of facilities. Some have comfy sofas, plasma screens, bars, dining tables and beds. They don't go very fast, as the extra work goes on making the inside extravagant rather than tuning the engine. Often, a camera sends images to the driver of the rear of the vehicle.

BIGGEST DUMP TRUCK

CATERPILLAR 797F

The Caterpillar 797F is the world's biggest dump truck, capable of carrying more than 360,000 kg of rock and soil. These trucks are called ultra-class haulers.

The 797F is often used at mining sites where up to 81,000 kg can be dragged from the ground at a single shovel pass. Using such a big dumper truck saves money, as fewer trips are needed to move the load from where it is dug from the ground.

CATERPILLAR 797F	
WHEN	2009
HOW HEAVY	623,690 KG
TOP SPEED	68 KM/H
SIZE	15 M LONG; 15.7 M HIGH (WITH BODY RAISED)
POWER	2,828 KW
ENGINE	CAT C175-20 ACERT

The truck is so tall the driver needs a ladder to get up to the cab.

The engine is huge, with 20 cylinders arranged in a single V-block. It has four turbo-chargers sucking air into the engine to enable it to burn fuel more quickly.

TOO BIG TO MOVE

The 797F is so big that it's put together at the customer's site. It's too heavy and wide to drive on public roads. It takes 12-13 semi-truck trailers to move all the parts – with two trucks just for the tyres, and four for the body. Putting it together takes seven engineers working round-the-clock for 20 days. If it has to be moved between sites, it must be taken apart and rebuilt afterwards.

The projecting shelf protects the cab from stray bits of load.

MINING ON MOUNTAINS

Some mining work takes place at high altitudes where the air pressure is low. This is a problem for engines that need lots of air to burn fuel. The 797F engine can be adjusted to work at sites up to 4,877 m above sea level – that's half the height of Mount Everest!

The 797F uses six of the largest tyres in the world: Michelin 59/80R63 XDRs. They're each 4 m tall, weigh 5,300 kg and cost $42,500.

REMOTE-CONTROL TRUCKS

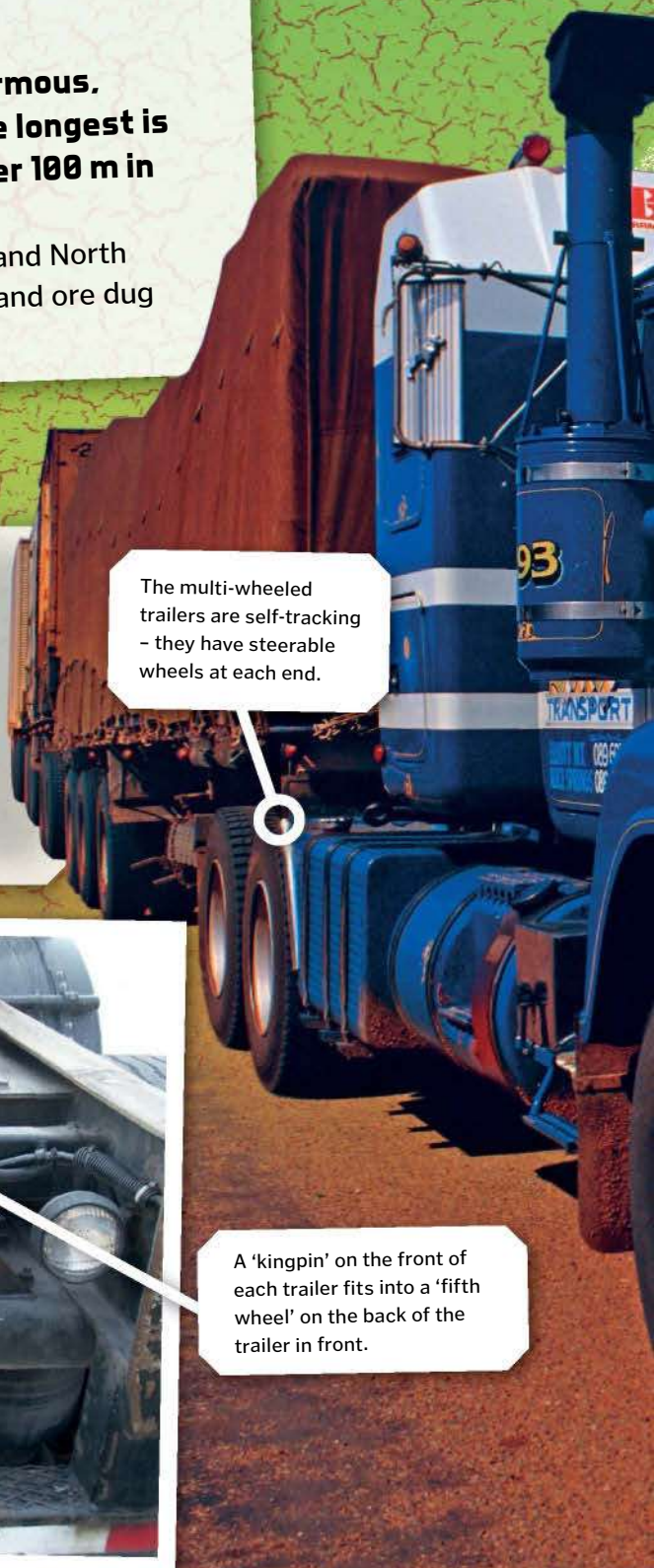
Some mines in Australia, the USA and Chile use small fleets of ultra-class haulers that are remote controlled, with no drivers. The vehicles use sophisticated GPS systems and a combination of radar sensors and cameras to move around, avoiding obstacles.

HEAVIEST HAULER

ROAD TRAIN

Road trains are chains of trailers pulled by enormous, powerful tractor units. The world record for the longest is held by a Mack Truck that pulled 112 trailers over 100 m in Clifton, Australia, in 2006.

Road trains are most common in Australia, Argentina and North America, where they are used to move livestock, fuel and ore dug from mines.



The multi-wheeled trailers are self-tracking – they have steerable wheels at each end.

HOW TO LINK UP A ROAD TRAIN

The fifth wheel is a horseshoe-shaped flat metal plate with a gap for the kingpin (see below) to fit into. When positioned, the kingpin locks in place but can swivel within the fifth wheel. A flat plate covers the fifth wheel. The same mechanism is used to couple the prime mover and the first trailer, and between trailers.

A 'kingpin' on the front of each trailer fits into a 'fifth wheel' on the back of the trailer in front.

BIGGEST HAULING TRUCK

The Liebherr T 282B is an off-highway truck for hauling powertrains (see right). It's a two-axle truck with a rigid frame and is diesel/electric powered. It can take a payload of 330,000 kg.

ALL IN A ROW

Most road trains have two to four trailers; those with five or six are called powertrains. Often, there's a second engine in the last trailer of the largest road trains, operated by remote control from the driver's cab. Without this help, the strain of pulling such weight can break the drive shaft of the prime mover, or unhitch the trailers.

In Australia, there's a weight limit of 115,000 kg and a length limit of 53.5 m for use on the roads. On private land, the legal limits don't apply and they can be real monsters!

The powerful truck at the front is the 'prime mover'. It has two drive axles and a single steer axle. It can be an articulated or rigid-bodied truck.

ROAD TRAIN

LENGTH	1,474.3 M
WEIGHT	1,279 TONNES
PRIME MOVER	MACK TITAN

BIGGEST BIKE

MONSTER MOTORBIKE

The Monster Motorbike weighs 13.6 tonnes and is 3 m tall. Ray Baumann, who built the bike in Perth, Australia, uses it to perform stunts, crushing cars and even caravans under its wheels.

The diesel truck engine has been adapted to be more like a regular bike engine. There's an automatic gearbox from a lorry and a differential from an articulated lorry that drives a massive chain on each side of the rear wheel.

Kevlar-like body plates for protection.

The wheels taken from a Caterpillar 80-tonne excavator have tyres 3 m tall that each weigh 2,700 kg.

BIGGEST YOU CAN BUY

The largest production motorbike is the Boss Hoss BHC-3 502 Big Block. Boss bikes have Chevrolet V8 engines with a capacity of up to 8,226 cc (8.2 litres). But what is 'biggest'? The bike with the most powerful engine or the bike that takes up most space? The Gunbus 410 has a smaller engine at 6,728 cc but weighs 650 kg, while the Big Boss weighs just under 500 kg.

MONSTER MOTORBIKE

WHEN	2008
HOW HEAVY	13.6 TONNES
SIZE	9.14 M LONG; 3 M TALL
ENGINE	DETROIT DIESEL TRUCK ENGINE

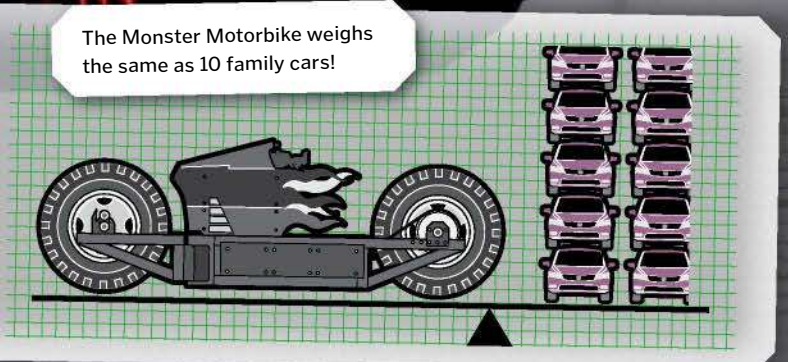
HEAVY METAL

The heaviest motorbike in the world is the 4,749 kg Harzer Bike Schmiede. It was built by Tilo and Wilfried Niebel in Germany and took a team of mechanics and welders a year to make. It's 5.28 m long and 2.29 m tall and is powered by an engine taken from an old Russian tank.

SIZE AND POISE

To stop the Monster Motorbike tipping over, there's a sump guard that weighs 1,180 kg, plus a metal plate beneath it that's 2.5 cm thick and weighs 1,200 kg

It's just 12.5 cm off the ground, so it keeps the bike's centre of gravity low.



LONGEST BUS

AUTOTRAM EXTRA

The longest ever bus is the AutoTram Extra first run in Dresden, Germany, which is 30.7 m long. The 'bendy bus' is cheaper to use than a normal tram, which runs on rails built into the road.

The bus is a hybrid: it has electric and diesel power. The lithium ion battery (on the roof of the second car) can run the bus for 8 km; then the diesel engine kicks in, recharging the batteries as it runs the bus.

Walk-through bendy joints between the three compartments make it as easy to manoeuvre as an ordinary bus.

LOOK - NO HANDS!

At the opposite extreme, the very short Park Shuttle in Amsterdam has a single compartment – and no driver. It uses no mechanical guidance, such as rails or overhead lines. Instead, it has a stored map of the location and compares its position with this, counting revolutions of the wheels to track how far it has gone. Magnets in the road are used by an onboard computer to check the position every now and then.

The tiny Park Shuttle is only a bit longer than a family car.

ROAD AND RAIL

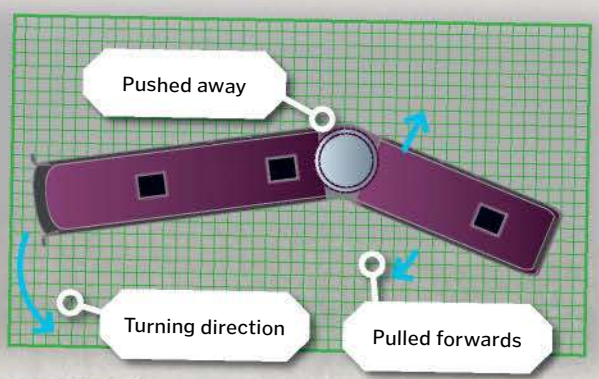
The DMV Bus Train, recently tested in Japan, combines the best of bus and train. It has two sets of wheels – steel wheels for using on the railway track and rubber-tyred wheels for using on the road. The driver can switch between wheels sets by lowering one and raising the other.

AUTOTRAM EXTRA

WHEN	2012
HOW HEAVY	42,235 KG
SIZE	30.7 M
COST	£778,000
POWER	455 KW (DIESEL); 420 KW (CAPACITORS); 120 KW BATTERY (ELECTRIC)

CORNERING A BENDY BUS

At the connections between carriages, the AutoTram has a universal joint with hinges on the side furthest from the driver's cab. As the bus turns, one side of the joint is brought closer to the carriage in front and the other side pushed further away.



BIGGEST LAND VEHICLE

BAGGER 288

The gigantic Bagger 288 is one of a series of similar bucket-wheel excavators which vie for the title of largest land vehicle on Earth.

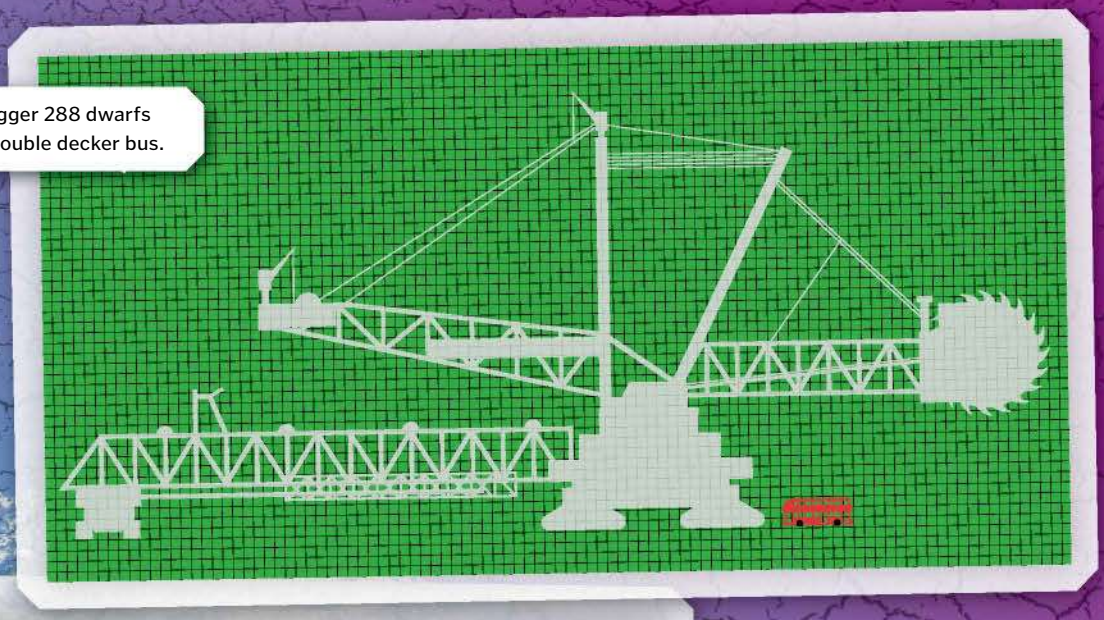
Instead of a single giant bucket, this type of excavator has a set of them arranged around a wheel. The buckets plough through the ground one after another as the wheel turns.

Bagger 288 can move 240,000 m^3 of material a day. That's the equivalent of making a hole the size of a football pitch and 24 metres deep in a single day.

CRAWLER

The Bagger moves really slowly – it travelled at the rate of 1 km/h to reach the mine in Germany where it works. Moving the bucket-wheel and counterweight booms is very slow, too – depending on the direction, they might move only 5 m in a minute.

A massive boom acts as a counterweight to the bucket-wheel arm to stop the Bagger tipping over. The two are connected and controlled by cables.



Bagger 288 dwarfs a double decker bus.

SENSITIVE SYSTEMS

The Bagger has five operators, but much of the work is automated with sensors, GPS, data acquisition systems and online monitoring. Sensors detect how much material is being moved and the speed of the conveyor belts is adjusted automatically. Managers and operators can track progress from data fed directly to the Internet.

BAGGER 288

WHEN	1978
HOW HEAVY	14,200,000 KG
TOP SPEED	1 KM/H
SIZE	220M LONG; 96M TALL

Each of the 20 buckets on the 23-m bucket-wheel can hold 5,500 m3 – about 80 bathtubs – of earth.

Earth and rubble are dropped through a chute onto a conveyor belt that takes them along the discharge boom to be dumped or spread on the ground.

SLOWEST CRAWLER

NASA CRAWLER

This giant crawler is used to move Space Shuttles to the launch sites. It's as wide as a six-lane highway and, carrying a rocket, as tall as a skyscraper. The crawler is too heavy for normal roads - it would destroy the road surface.

The Space Shuttles make their final journey, or roll-out, to the launch pad already fitted to their mobile launcher. The trip of just under 5.5 km takes six hours as it has to go so carefully and slowly.

PRECISION WORK

Hydraulics move the platform to the right level to shift the spacecraft from its support pedestals onto the crawler, and from the crawler onto the launch tower. It takes 30 minutes to move the platform up to receive the Shuttle. The hardest part is driving it up a ramp to the launch position. The crawler uses precision laser equipment to get the Shuttle in just the right place.

NASA CRAWLER

WHEN	1963
HOW HEAVY	2,495,000 KG; 8,000,000 KG (LOADED)
TOP SPEED	9.66 KM/H (BUT ROUTINE SPEED IS 1.6 KM/H)
SIZE	34.4 M WIDE 9.5 M LONG
FUEL CONSUMPTION	355 LITRES PER KM
POWER	2 x 2023 KW ENGINES

A house on the road in 1940s America.

MOVING HOUSE

Nothing is as big as the crawler – but large vehicles have been used to move enormous loads since the invention of the truck.

Front and rear driver cabs and on-board bathroom and kitchen facilities for staff who take 14 hours to load, move and unload the Shuttle.

WEIGHT LIFTER

Carrying a Shuttle and launcher or a rocket, the crawler weighs a massive eight million kilograms. That takes a lot of power to move. Two diesel engines drive an electric motor that moves the crawler.

One crawler is being upgraded to carry 8,165,000 kg so that it can move NASA's new heavy-lift rockets.

LARGEST WINGSPAN

SPRUCE GOOSE

The Hughes H-4 Hercules Spruce Goose had a wingspan of an amazing 97.54 m, making it the largest ever to fly. It was also the largest-ever flying boat. It was a prototype and the only one ever built.

Because of war-time restrictions on the use of aluminium when it was built, the Spruce Goose was made mostly from wood. It could carry 750 soldiers, with all their equipment, or a single tank.

BIG WINGS, NO ENGINE

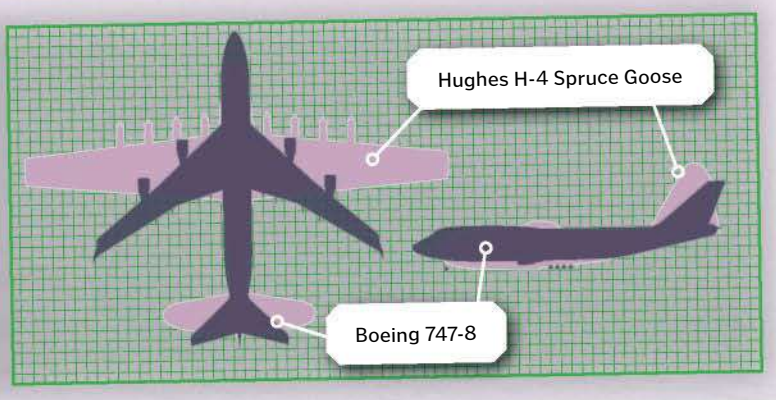
Gliders have a very large wingspan with a small, light body. As they have no engine, they depend entirely on lift from the air beneath their huge wings. The wings are very long and narrow, as this is the best aspect ratio for maximising lift and reducing drag.

SPRUCE GOOSE

WHEN	1947
HOW HEAVY	180,000 KG (LOADED)
TOP SPEED	408 KM/H (CRUISE SPEED, NOT TOP SPEED)
SIZE	66.65 M LONG; 24.18 M WIDE
POWER	21,120 KW

WIDE, NOT LONG

The Goose was designed to carry troops across the Atlantic during the Second World War, but was completed in 1947 after the war ended. It made a single test flight, then never flew again, although it awas maintained in flying condition until 1976. It remains the plane with the largest-ever wingspan, but modern jumbo jets are longer.



The fuselage and wings were made from a wood-and-resin composite; the rudder and elevators were covered with fabric.

Each wing had four Pratt & Whitney R-4360 Wasp Major radial engines, each with a single four-blade propellor.

The fuselage had a single, large space with no windows for carrying troops and equipment.

TINY WINGS

The wingspan of the Stits Baby Bird is only 1.93 m. It's a high-wing monoplane with space for the pilot only. At 3.35 m long and weighing 114.3 kg, it has a maximum speed of 177 km/h and can climb to 2,880 m. The fuselage is made of steel tubing and the wings of wood.

LARGEST JUMBO JET

AIRBUS A380-800

The Airbus A380-800 is the largest jumbo jet in the world. It can carry 853 passengers over two floors. It has four jet engines, each producing 310,000-340,000 N of thrust depending on which engine type the client airline chooses.

It has a flying range of 15,700 km – far enough to go from New York to Hong Kong – which it can manage because it can carry 320,000 litres of fuel. It can fly up to 13,000 m – nearly 4 km higher than Mount Everest.

Together, the four engines use a litre of fuel every second.

QUALITY RIDE

Although the Airbus can take 853 people if all fly economy class, the seats can be moved to provide 521 seats in three classes, including an extravagant first class area. There can be seats that recline into beds and comfortable lounge and bar areas.

Quality or quantity? The Airbus is flexible.

PUTTING IT ALL TOGETHER

Large sections of the A380 are built in France, Germany, Spain and the UK. They are all moved to Toulouse in France by road, ferry and air. Smaller parts come from around the world. A network of ferries, adapted roads, canal barges and specially built port facilities was created to move the large components. The aircraft are assembled in Toulouse and flown to Hamburg for furnishing and painting.

It takes 3,600 litres of paint to cover the plane's surface, which has an area of 4,400 m2. The paint alone weighs 500 kg!

There is 530 km of wiring used in the plane. The cabin has a whopping 98,000 separate wires as well as 40,000 connectors.

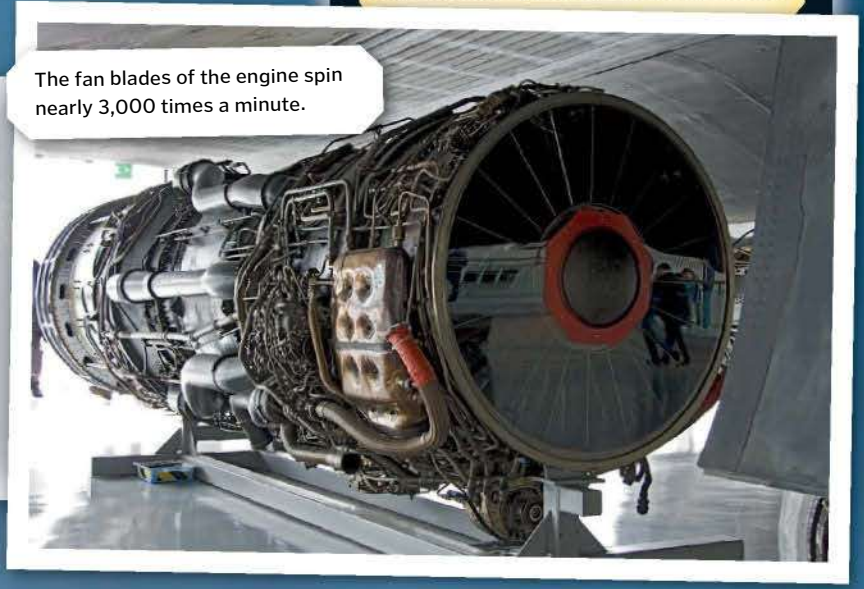
The landing gear has four main landing legs and a nose leg, with a total of 22 wheels.

AIRBUS A380-800

HOW HEAVY	276,800 KG (EMPTY)
TOP SPEED	945 KM/H
SIZE	72.73 M LONG; 79.75 M WINGSPAN

JET ENGINES

The huge jet engines used in planes are also called gas turbines. A fan sucks air into the front of the engine. The air is compressed and mixed with fuel, and an electric spark sets light to the mixture. The burning gases blast from the back of the engine, so the engine and the aircraft are thrust forward.



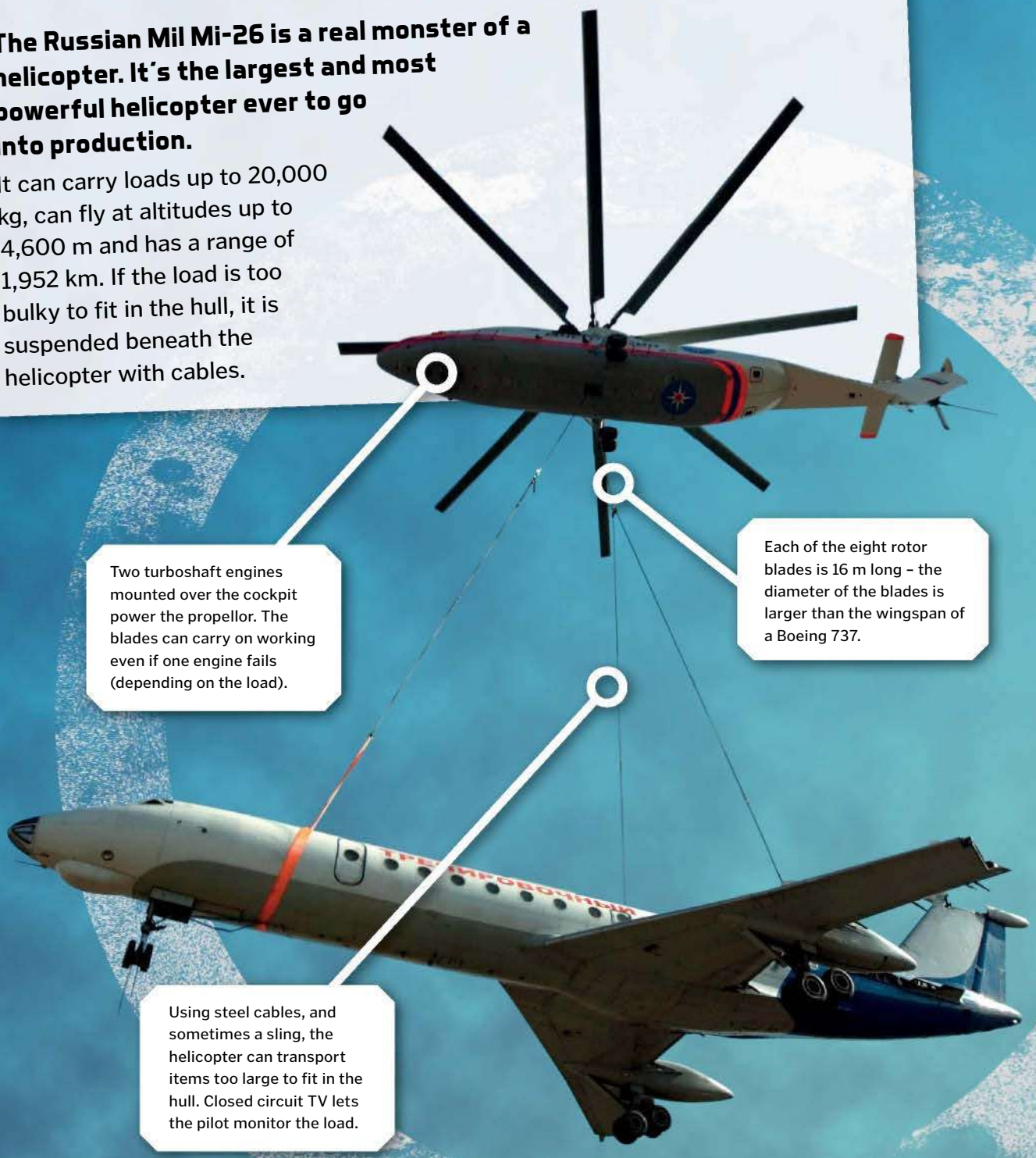
The fan blades of the engine spin nearly 3,000 times a minute.

BIGGEST HELICOPTER

MIL MI-26 HELICOPTER

The Russian Mil Mi-26 is a real monster of a helicopter. It's the largest and most powerful helicopter ever to go into production.

It can carry loads up to 20,000 kg, can fly at altitudes up to 4,600 m and has a range of 1,952 km. If the load is too bulky to fit in the hull, it is suspended beneath the helicopter with cables.



Two turboshaft engines mounted over the cockpit power the propellor. The blades can carry on working even if one engine fails (depending on the load).

Each of the eight rotor blades is 16 m long – the diameter of the blades is larger than the wingspan of a Boeing 737.

Using steel cables, and sometimes a sling, the helicopter can transport items too large to fit in the hull. Closed circuit TV lets the pilot monitor the load.

PLENTY OF ROOM INSIDE

The giant hull of the Mil has a cargo bay that can take tanks and other vehicles, or up to 80 people for troop movements or medical evacuations. Two electric winches on overhead rails can move loads along the cabin. Each is capable of carrying 2,500 kg. The floor has tie-down rings for securing loads.

MAMMOTH CARRYING A MAMMOTH

In 1999, a Mi-26 was used to transport a massive block of ice containing the frozen remains of an extinct Siberian mammoth, over 20,000 years old, to a science lab. The ice block weighed nearly 23,000 kg. The helicopter had to be returned to the factory and checked for damage immediately after the mission as the frozen mammoth was over the weight limit for lifting.

SMALL HOVERER

The tiny Hummingbird hover platform is just 2.2 m across. It has four small internal combustion engines capable of running the vehicle at up to 74 km/h. With a maximum hover height of 1,500 m, it can stay in the air for up to 30 minutes. The operator stands up, guiding the vehicle by shifting his or her weight. The Hummingbird is sold as a kit and takes 250 hours to build.

The pilot has to stand up for the ride on the platform.

MIL MI-26 HELICOPTER

WHEN	1977
HOW HEAVY	28,200 KG
TOP SPEED	295 KM/H
SIZE	40 M LONG, 32 M ROTOR DIAMETER
POWER	16,740 KW

LARGEST POWERED AIRSHIP

BULLET 580

At 71.6 m long, Bullet 580 is the largest inflatable powered airship. It can carry a load of 907 kg up to a height of 6 km.

This gigantic balloon took six hours to inflate. It can be flown by a crew or remotely controlled. Despite its size, it can operate from a small area as it takes off and lands vertically. The top speed is 129 km/h, but it doesn't have to go fast – it can hover over the same spot for up to a week!

The engine (not visible) runs on bio-fuel made from algae.

The outer envelope is made of Kevlar and is just over 1.5 mm thick, but it's ten times stronger than steel. If it has a hard landing, the balloon should just bounce!

BLIMPS AND RIGID AIRSHIPS

Airships can be non-rigid (a floppy skin that is inflated like a regular balloon), semi-rigid, or rigid. A semi-rigid airship has a solid framework but a floppy envelope. A rigid airship has a rigid envelope. Early rigid airships were made of canvas stretched over a wooden frame and then stiffened and made waterproof with resin. Blimps are non-rigid airships, like a giant balloon.

BULLET 580

WHEN	2013
TOP SPEED	129 KM/H
SIZE	71.6 M LONG; 19.8 M DIAMETER - ABOUT 22,000M3
COST	$8,275,000

The horrific Hindenburg disaster stopped people from wanting to travel by airship.

BIGGER, BUT NOT BETTER

An even larger airship, but rigid-bodied, was the German airship Hindenburg. It was the last of the great airships of the early twentieth century. The Hindenburg burst into flames when landing in 1937, killing 37 people. Early airships, including Hindenburg, were filled with hydrogen. It is lighter than the helium used now, but highly inflammable.

Lift is provided by seven vast internal bags of helium, a gas lighter than air but that can't burn in an accident.

EARLY BALLOONS

Hot-air balloons were the first vehicles to take to the skies. Normal air was heated inside a balloon-shaped envelope by a fire. The pilot and passengers stood in a basket suspended beneath the balloon. The first flight was made in Paris by the Montgolfier brothers in 1783. In 1852, another French engineer, Henri Giffard, flew the first steam-powered airship.

LONGEST SHIP

SEAWISE GIANT

The world's largest supertanker was Seawise Giant, an ultra-large crude carrier. It was powered by the largest diesel engine in the world. At its top speed of around 30 km/h it took 8.9 km to stop.

Although not quite the heaviest ship ever built, Seawise Giant was the longest. It worked transporting oil, but was bombed and sank during the Iran-Iraq war in 1988. It was salvaged and repaired and sailed until 2004. It then served as a floating oil storage container, but was scrapped in 2010.

The name of the ship changed several times. It was called Knock Nevis when it finally retired.

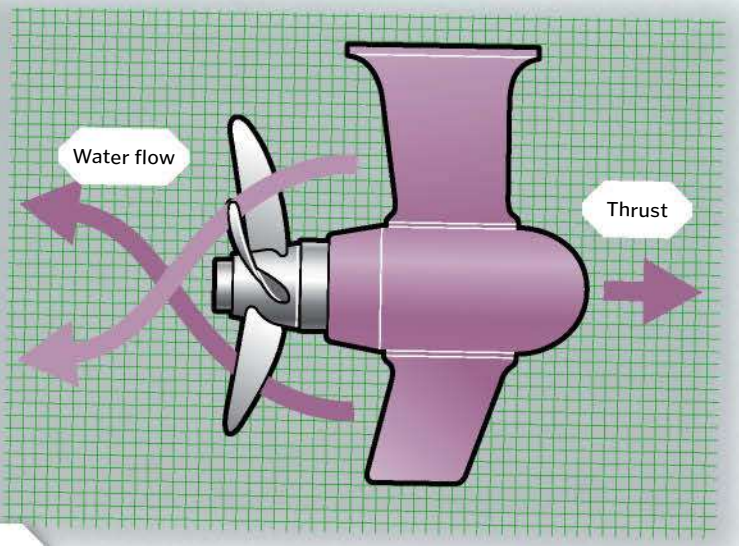
The distance from the waterline to the bottom of the keel was 24.6 m, making it too big to navigate the Panama Canal or the English Channel.

BIG PARTS

Every bit of Seawise Giant was huge. The anchor alone weighed over 30,000 kg. The rudder weighed 208,000kg and the propellor was 9 m across and weighed 45,000 kg. The displacement of the whole ship, when loaded, was 646,642,000 kg. The weight of a ship is given as the mass of water it displaces.

STEERING A GIANT

As the five-blade propellor of a ship like Seawise Giant turns, it creates both pushing and pulling forces on the water. The water is pulled into the turning propellor and forced out of the back, creating a jet effect which pushes the ship forwards. A rudder controls the direction the ship goes in. The flat blade of the rudder redirects the stream of water flowing round the hull and so turns the ship to the side.



The propeller draws water in and forces it backwards, pushing the ship forwards.

Seawise Giant had 31,541 m2 of deck space and over 46 tanks for holding crude oil.

The massive ship could carry more than half a billion kilograms of cargo, supplies and fuel – its so-called 'deadweight' capacity was 564,650,000 kg.

SEAWISE GIANT

WHEN	1981
HOW HEAVY	646,642,000 KG (LOADED DISPLACEMENT)
TOP SPEED (KPH)	30.6 KM/H
SIZE	458.45 M LONG
COST	$29,000,000
POWER	80,080 KW; 37300 KW

JUMBOISATION

Originally, Seawise Giant was going to be smaller. When the company that first ordered the ship cancelled the order, the hull was cut in half and an extra section added, making it longer – a process called 'jumboisation'. The company building it thought a bigger ship would be easier to sell.

BIGGEST LINER

ALLURE & OASIS OF THE SEAS

Giant passenger liners are more than floating hotels - they can be like small towns that sail the oceans.

Sister ships Allure of the Seas and Oasis of the Seas are massive – they each carry 5,400 passengers (6,296 maximum) and have a crew of 2,384. At 362 m long, they are the largest liners in the world. Allure of the Seas is 50 mm longer than its sister ship Oasis of the Seas. Each hull alone weighs 49,000,000 kg. There are 18 lifeboats that each hold 370 people – enough for 6,660 people.

Three 20,000-kW thrusters under the stern use electric motors to drive 6-metre propellers. There are no rudders; the ship is steered by moving the angle of the propellers.

THIRSTY SHIPS

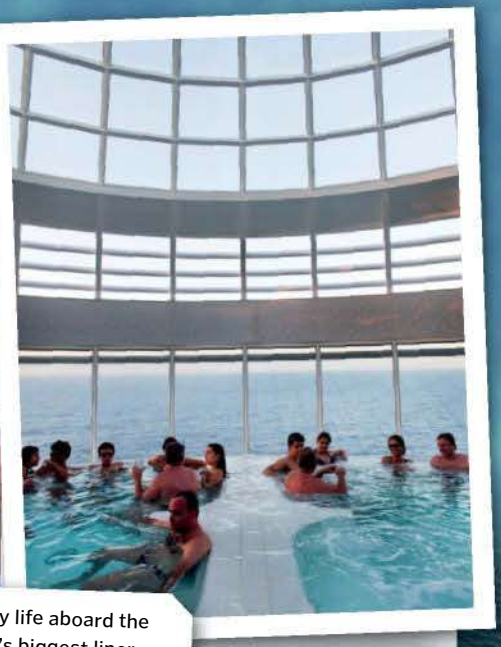
Both ships use 5,210 litres of fuel per engine per hour for the 16-cylinder engines and 3,910 litres for the 12-cylinder engines – a total of 9,120 litres an hour.

ALLURE OF THE SEAS

WHEN	2010
HOW HEAVY (KG)	90,700,000 KG (LOADED DISPLACEMENT)
TOP SPEED (KPH)	42 KM/H
SIZE	362 M LONG; 65 M WIDE; 72 M TALL
COST	$1.2 BILLION
POWER	97,020 KW

LUXURY ON THE WAVES

Each of the ships has a dance hall that extends to two decks, a theatre to seat an audience of 1,380, a skating rink and a shopping mall. But that's not all. There are a zip-line, a mini-golf course, five swimming pools, a gym, volleyball and basketball courts, theme parks, night clubs, a spa especially for teens, a carousel, a science lab for young people, karaoke and comedy clubs. There's even a living park with 12,000 plants and 56 trees!



Luxury life aboard the world's biggest liner.

The telescoping funnels can be contracted to pass under bridges.

The best suites are two-storey lofts and luxury suites of 150 m2 with sea-view balconies.

POWERING IT

Each ship has six medium-speed marine diesel engines: three with 16 cylinders and three with 12 cylinders. Together, they produce 97,020 kW of power that's converted to electricity. The electricity propels the ship and also powers the lights, elevators and everything else the ship needs.

HOW IT WORKS

WORLD'S FASTEST VEHICLES

HOW IT WORKS BOOK OF MEGA MACHINES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WORLD'S FASTEST VEHICLES

BLOODHOUND SSC

Blink and you'll miss these speed machines, but what high-octane engineering is under the hood?

In 1906, on the sands of Ormond Beach in Florida, USA, mankind's obsession with speed shifted into a new gear. Powered by kerosene-burning steam engines, the world's first racecars broke the 160-kilometre (100-mile)-per-hour mark, igniting a race for the record books – one that roars on today.

The Bloodhound SSC, in development, hopes to speed past the 1,600-kilometre (1,000-mile)-per-hour barrier, smashing the current land-speed record by nearly 400 kilometres (250 miles) per hour and reaching a velocity that could outrun a Magnum .357 bullet. Building the world's fastest vehicles on land, air and sea is equal parts physics, robust materials and imagination. As long as there's a new milestone to reach – the speed of sound, perhaps even the speed of light – our brightest minds will take on the challenge.

BLOODHOUND SSC

LENGTH	13.5 M (44 FT)
POWER	ROLLS-ROYCE EJ200 JET ENGINE AND HYBRID ROCKET
TOP SPEED	1,690 KM/H (1,050 MPH)
WEIGHT	7,786 KG (17,165 LB)
COST	£15 MN ($25 MN)
NUMBER OF PASSENGERS	1

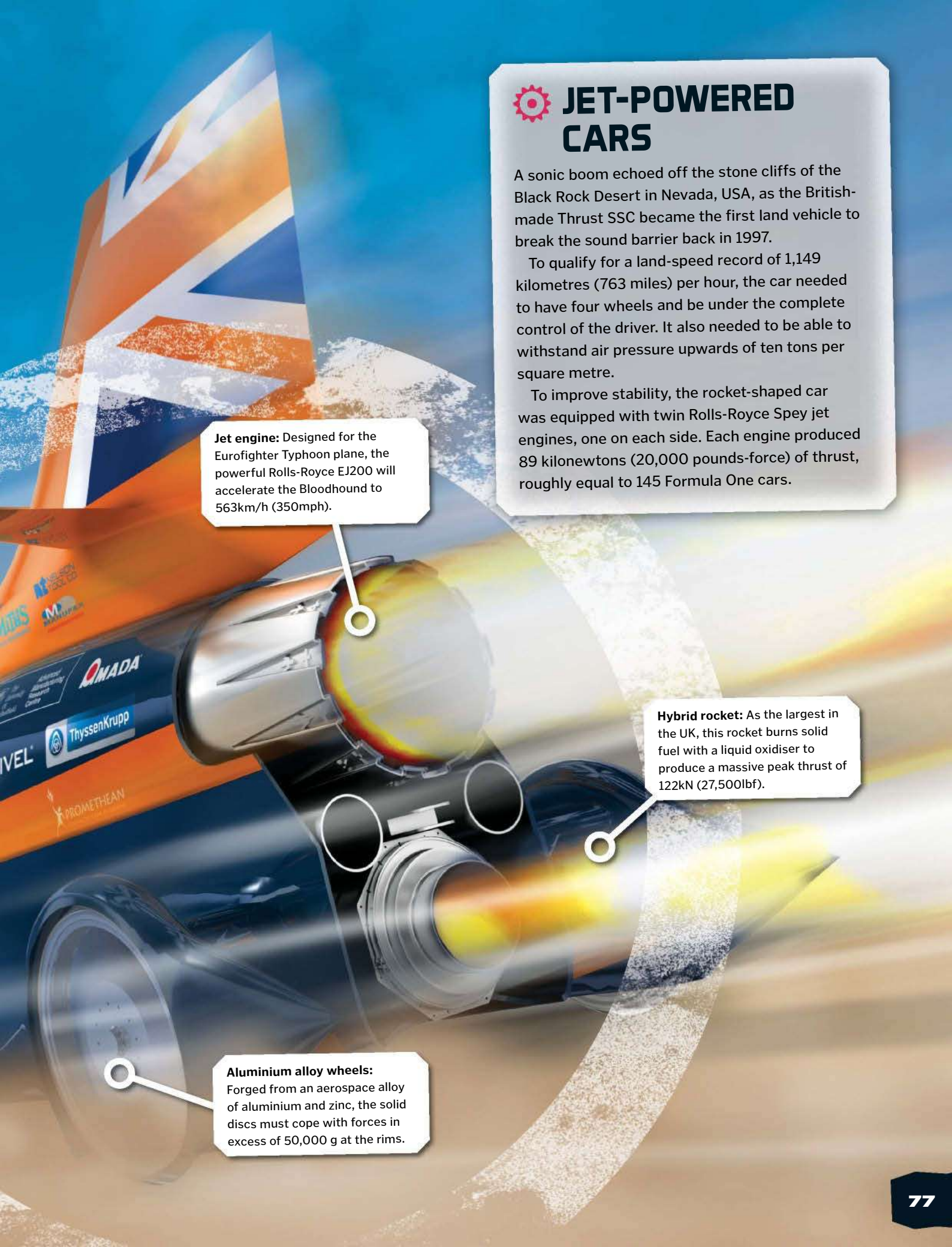
F1 engine: Custom-built by Cosworth, this 559kW (750hp) engine will pump 800 litres of high-test peroxide oxidiser to the hybrid rocket.

JET-POWERED CARS

A sonic boom echoed off the stone cliffs of the Black Rock Desert in Nevada, USA, as the British-made Thrust SSC became the first land vehicle to break the sound barrier back in 1997.

To qualify for a land-speed record of 1,149 kilometres (763 miles) per hour, the car needed to have four wheels and be under the complete control of the driver. It also needed to be able to withstand air pressure upwards of ten tons per square metre.

To improve stability, the rocket-shaped car was equipped with twin Rolls-Royce Spey jet engines, one on each side. Each engine produced 89 kilonewtons (20,000 pounds-force) of thrust, roughly equal to 145 Formula One cars.



The HTV-2 test flight lasted about nine minutes, before heat damage forced the mission to be terminated.

HTV-2

The engineering challenges for high-speed aircraft are surprisingly similar to building the world's fastest cars. Drag is still the biggest problem. As an aircraft approaches the speed of sound, the gas flowing around the plane grows more viscous, 'sticking' to the surface and changing the aerodynamic shape of the craft. Any friction with that high-velocity stream of gases will cause turbulence, incredible heat and shockwaves. To achieve the best aerodynamic profile, supersonic planes have swept-back wings that stay safely inside the cone of a supersonic shockwave.

John Kiewicz drove the Hennessey Venom for the acceleration record.

SPEED VS ACCELERATION

In January 2013, a Hennessey Venom GT ripped down an airport runway in Texas to break the world acceleration record: 0-300km/h (186mph) in 13.63s. Acceleration is not the same as speed. Acceleration is a product of the V8 engine's torque (force) divided by the Venom GT's mass (ie a = f/m). The Venom accelerates so quickly because its lightweight 1,244kg (2,743lb) frame is cranked by 160kg/m (1,155lb/ft) of torque. The heavier Bugatti Super Sport loses to the Venom GT in a sprint, but can hold the road at higher maximum speeds.

WORLD'S FASTEST MANNED AIRCRAFT

The fastest-ever manned aeroplane made its record-setting flight 47 years ago. In the early days of the Space Race, the X-15 was designed to test the limits of aeronautical engineering at the edge of space. Built like a short-winged fighter jet, the X-15 packed a rocket under its hood. To fly, it would hitch a ride on a massive B-52 up to 13,700 metres (45,000 feet). Dropped from the bomber, the X-15 lit its liquid propellant rocket capable of 500,000 horsepower. The X-15 only carried enough fuel for 83 seconds of powered flight – but it was enough to rocket its pilots into the record books.

The X-15 craft first created its record 47 years ago and is unbeaten to this day.

The Venom GT uses a modified version of the Lotus Exige chassis.

INCAT FRANCISCO

It's one thing to see a tiny speedboat race across the ocean surface, but it's downright mind-blowing to watch a 99-metre (295-foot) ferry hit speeds of more than 50 knots (93 kilometres/58 miles per hour) while carrying up to 1,000 passengers and 150 cars. The Francisco is Australian shipmaker Incat's latest breakthrough; a twin-hulled catamaran powered by two massive turbine engines running on liquefied natural gas (LNG). The turbines force water through two enormous waterjets that propel and steer the craft, which cuts through the waves like a warm knife through butter. The Francisco will ferry passengers in style and speed from Buenos Aires in Argentina, to Montevideo in Uruguay.

The Incat Francisco is the fastest passenger ferry on the waves.

The speed comes from the Incat's LM2500 marine gas turbine.

INCAT FRANCISCO

LENGTH	99 M (325 FT)
TOP SPEED	107.4 KM/H (66.7 MPH)
DEADWEIGHT	450 TONS
CARS	150
PASSENGERS	1,000

SCORPION FV101

The lightweight and agile Scorpion FV101 boasts a perfect combination of speed and toughness for warzones.

Weighing only eight tons, the Scorpion is very fast and can run circles around battle tanks.

The new L0 maglev train being tested in Japan has already clocked 500km/h (311mph).

L0 MAGLEV

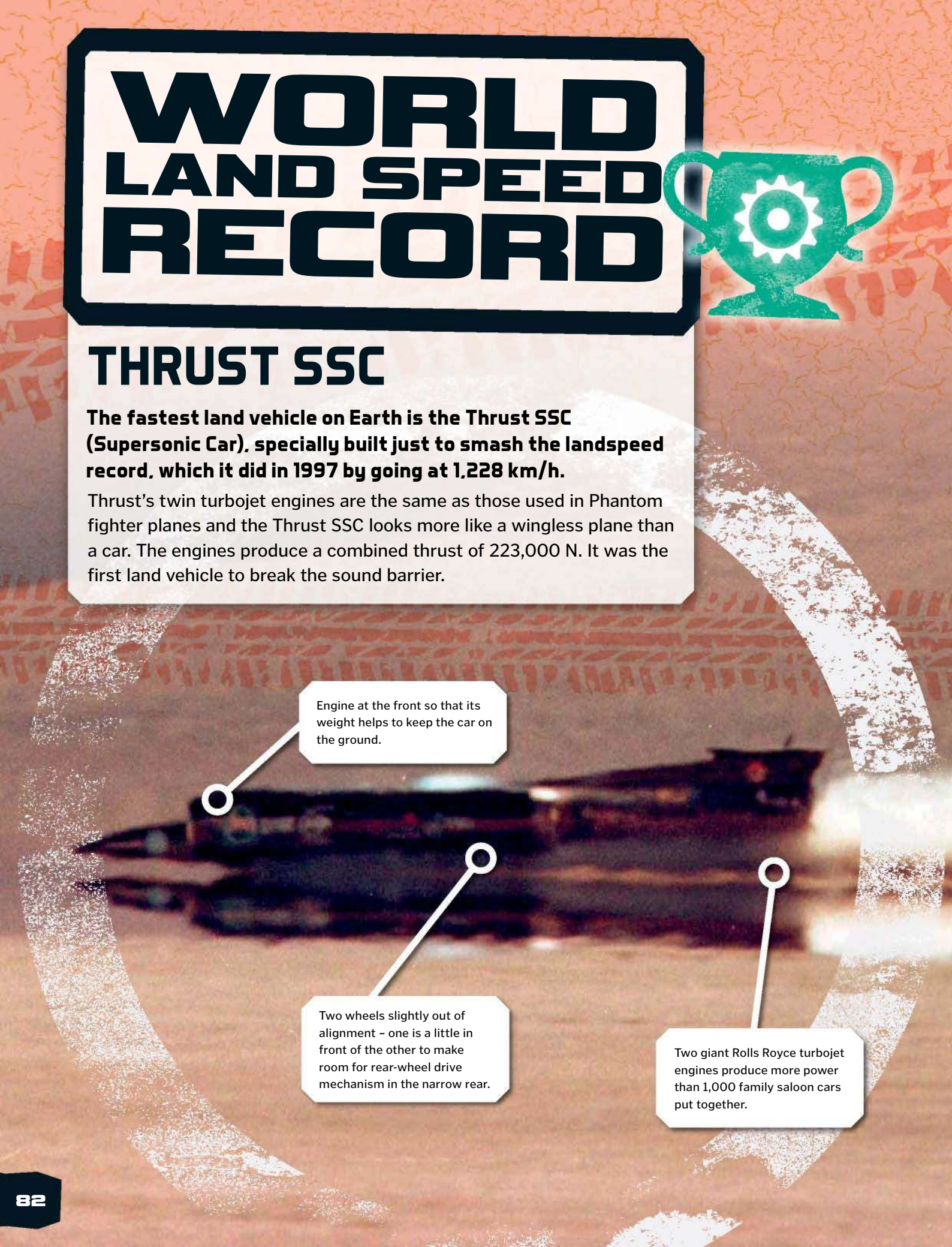
The future of high-speed trains is without a doubt magnetic. The principle of magnetic levitation (maglev) allows trains to reduce drag by floating on a one to ten-centimetre (0.4 to four-inch) cushion of air created by opposing electromagnetic fields in the track and car. The Shanghai Maglev Train in China became the first commercial maglev in 2003 and still holds the operational speed record for a commercial train: 431km/h (268mph). Today, conventional high-speed lines in Spain, France, Italy, South Korea and elsewhere reach speeds exceeding 300km/h (186mph), using a combination of streamlined aerodynamics, lightweight plastics and electric-powered locomotives.

WORLD LAND SPEED RECORD

THRUST SSC

The fastest land vehicle on Earth is the Thrust SSC (Supersonic Car), specially built just to smash the landspeed record, which it did in 1997 by going at 1,228 km/h.

Thrust's twin turbojet engines are the same as those used in Phantom fighter planes and the Thrust SSC looks more like a wingless plane than a car. The engines produce a combined thrust of 223,000 N. It was the first land vehicle to break the sound barrier.



NEXT ATTEMPT

Richard Noble, the designer of Thrust SSC, wants to break his own record in a new car, the Bloodhound SSC. He hopes it will travel at 1,600 km/h. The engines will deliver 100,000 kW – more than six times the total power of all the Formula 1 cars that compete in a race. The front half has the carbon monocoque construction of a racing car and the rear half has the metal construction of an aeroplane.

THRUST SSC

WHEN	1997
HOW HEAVY	10.5 TONNES
TOP SPEED	1,228 KM/H
ACCELERATION	0-1,000 IN 16 SECONDS
FUEL CONSUMPTION	0.2 KM/LITRE
POWER	82,000 KW
ENGINE	TWO ROLLS ROYCE TURBOJET ENGINES

Spirit of America created a new category of records.

FIRST LANDSPEED RECORD HOLDER

The very first landspeed record holder was Spirit of America, which set the record in 1963. With three wheels, and a turbojet engine, it travelled at 655.7 km/h, setting the first record for a jet-propelled car.

GOING AND STOPPING

Thrust SSC can accelerate to 1,000 km/h in only 16 seconds and reach a top speed of 1228 km/h. To do that, it burns 18 litres of fuel a second and uses about 5.5 litres per kilometre – so travelling less than 200 m on a litre of fuel. To slow down, it first deploys a parachute and only uses its brakes when the speed has dropped low enough not to damage the brakes.

FASTEST THING ON TWO WHEELS

TOP 1 ACK ATTACK

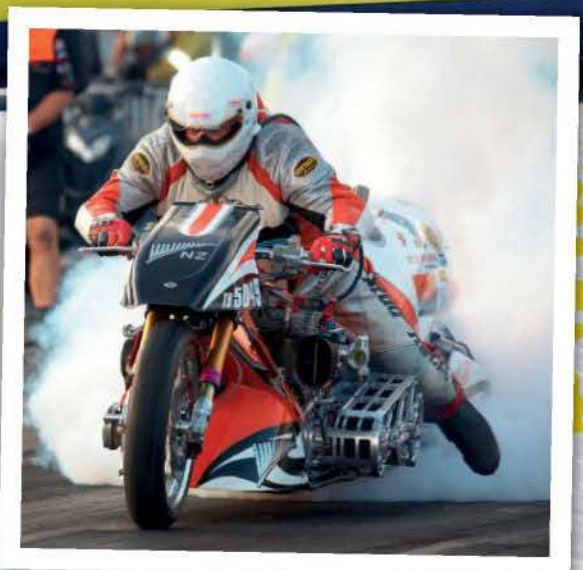
Not all vehicles are designed to go on the road. The fastest thing on two wheels is the TOP 1 Ack Attack, a specially designed motorbike made just to challenge the motorcycle world speed record.

The Ack Attack doesn't look like a motorbike because it's completely covered in an aerodynamic shell to make it cut through the air easily. It broke the world record on the Bonneville Salt Flats, Utah, USA in 2010 travelling at 605.697 km/h.

Rider is enclosed inside the vehicle shell, keeping the shape uninterrupted.

Streamlined shape like a bullet that is low to the ground to increase traction and reduce drag.

DRAG-BIKE RACING



FASTEST ON THE ROAD

You won't see the Ack Attack on the roads, but you might just see the fastest production motorbike, the Suzuki Hayabusa. It can travel at up to 303 km/h, using a 1,299-cc engine that delivers 128.4 kW. The Hayabusa will remain unchallenged in Europe as new regulations have set a top speed capability of 300 km/h, with bikes limited electronically so that they can't go faster.

The Hayabusa can accelerate to 306 km/h in under 10 seconds.

WHAT MAKES A MOTORBIKE FAST?

An engine that delivers a lot of power is obviously important for speed. But that's not all that matters. The vehicle must also have a streamlined shape – one that moves through the air (or water, for boats) easily without bits that stick out and create drag. For a motorbike or bicycle, the rider's position matters, too. A rider sitting upright impairs the streamlining. That's why riders crouch low over the handlebars.

Carbon-fibre body built on a chrome-molybdenum frame.

TOP 1 ACK ATTACK

WHEN	2010
HOW HEAVY	727 KG
TOP SPEED	606.697 KM/H
POWER	671 KW
ENGINE	2600 CC - TWO SUZUKI HAYABUSA TURBOCHARGED ENGINES

GREATEST MARINE MARVELS

XSR48 SUPERBOAT

The world's first superboat is a £1.2 million pound masterpiece. As you'd expect, only super-level engineering has been used to create it...

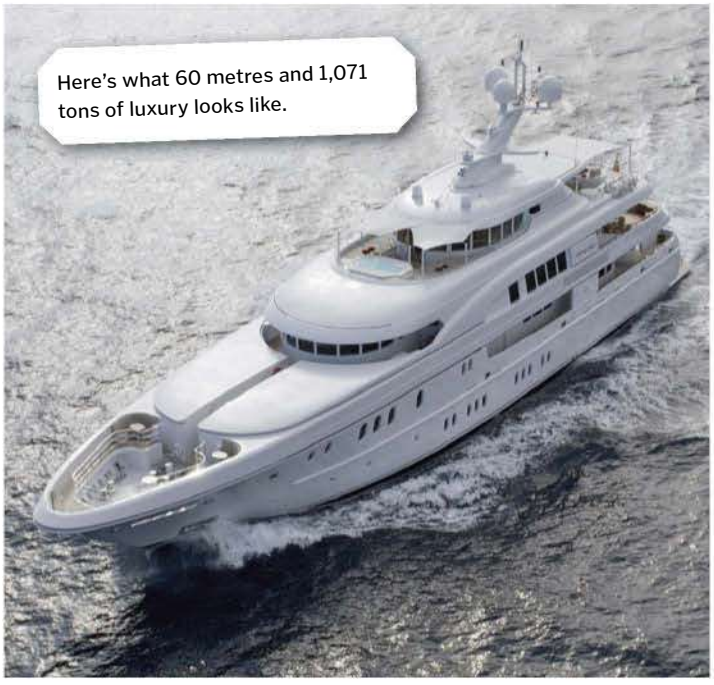
No speedboat like the XSR48 has ever existed. It is such a revolutionary machine, a new term had to be invented: meet the world's first superboat! Two world powerboat champions conceived it, and developed it with experts. High power is essential; the minimum output of the XSR48's twin turbodiesel engines is in excess of 1,600bhp.

XSR SUPERBOAT

MANUFACTURER	XSMG World
UNIT PRICE	£1.2 million
DIMENSIONS	Length: 14.6 M, beam: 3.19 M, height overall: 3.1m, above water: 2.2m
DISPLACEMENT	8,750 KG
ENGINE	Two 10.3 L Seatek 820 Plus Turbo - 603 KW
FUEL	Diesel, capacity 1,000 litres
TOP SPEED	70 knots
HORSEPOWER	1,640 BHP (standard), 1,900 BHP (max)

STABility: A patented STAB stabilisation system counteracts unsettling roll and pitch by means of hydrofoils.

Tested to extremes: Developers tested the XSR48 at speeds in excess of 100mph – in the most extreme sea conditions.



Here's what 60 metres and 1,071 tons of luxury looks like.

LÜRSSEN ARKLEY

Lengthier and more voluminous than the smaller 40-metre Ocean Pearl, the Arkley by Lürssen is characteristic of the latest generation of super yachts. In terms of statistics the Arkley doesn't disappoint, sporting a 60-metre length and a displacement of 1,071 tons, the yacht is powered by twin Caterpillar 3512 B 1,455 kW diesel engines that produce a combined 3,958 hp. This colossal power allows for a top speed of 15.5 knots and a max range of 7,000 nautical miles. It is not short of juice either, with the yacht packing three Caterpillar C18 generators that provide the ship's electronics with a total 903kW of energy.

Speedy: A high deadrise hull means high speeds can be achieved even in high wave seas; it stops the XSR48 launching off one wave and crashing hard onto the next.

Hull and deck: These are made from Kevlar and carbon fibre. This makes it very strong and rigid, and enables it to have the full-length glass roof.

OCEAN PEARL

The 40-metre long Ocean Pearl, the latest in the line of YachtPlus's 'Signature Series' of super yachts, was the result of a design process that took over 15 months by a team of seven architects under the watchful eye of Lord Norman Foster, and the technical expertise of the Rodriquez shipyard in Italy.

The result is a yacht with over 30 per cent more space than on any other yacht in its category. It has a top speed of 17.5 knots and a regular cruising speed of 16 knots.

The YachtPlus 40 'Signature Series' brings a contemporary style to nautical tradition.

FASTEST RACERS

TOP-FUEL DRAGSTER

The fastest racing cars on Earth are top-fuel dragsters. They have the fastest acceleration of any land vehicle, going from 0 to 200 km/h in less than a second.

Dragsters race over very short distances. The race starts with a burst of flame and a roar of engines and is over in five or six seconds! Dragsters race in pairs, with the winner going on to compete again. It's not just a race to the finish: electronics monitor reaction time (how long it takes the driver to start), the time taken to cover the track and top speed. The winner is the car to finish in the shortest time.

ON YOUR MARKS...

Before the race starts, the cars perform a 'burnout'. They drive over the start of the track, heating up the tyres and laying down a thin film of rubber on the road. It makes the tyres and road sticky, increasing traction for the wheels.

Each car lays down its own non-slip slick of rubber at burnout.

PIMP MY RIDE

Although top-fuel dragsters are designed for speed, amateur drag racing has lots of cars designed to look wacky as well as go fast.

TOP-FUEL DRAGSTERS

TOP SPEED	483 KM/H
ACCELERATION	0-200 KM/H IN LESS THAN A SECOND
POWER (KW)	5,966 KW
ENGINE	8.9 LITRE

A rear wing catches the air and prevents the car lifting off the road.

After the race, parachutes are used to slow the car down and avoid excessive wear on the carbon-fibre brakes.

LOOKING INSIDE

The engine is typically a supercharged V8. The supercharger forces air at higher than atmospheric pressure against the pistons, increasing the power the engine generates. A dragster can get through 5 litres of rocket fuel (nitromethane) a second and generates a force of 5G – five times the force of gravity! Fuel is pumped into the pistons so fast there isn't time for it all to burn, so some is expelled while still burning.

Burning fuel mixed with waste gases produce dramatic jets of fire.

FASTEST TRUCK

SHOCKWAVE

The world's fastest truck, called Shockwave, is powered by three jet aircraft engines. It can reach a top speed of 605 km/h. Shockwave is used in dramatic displays, racing jet aircraft that fly above it - and winning!

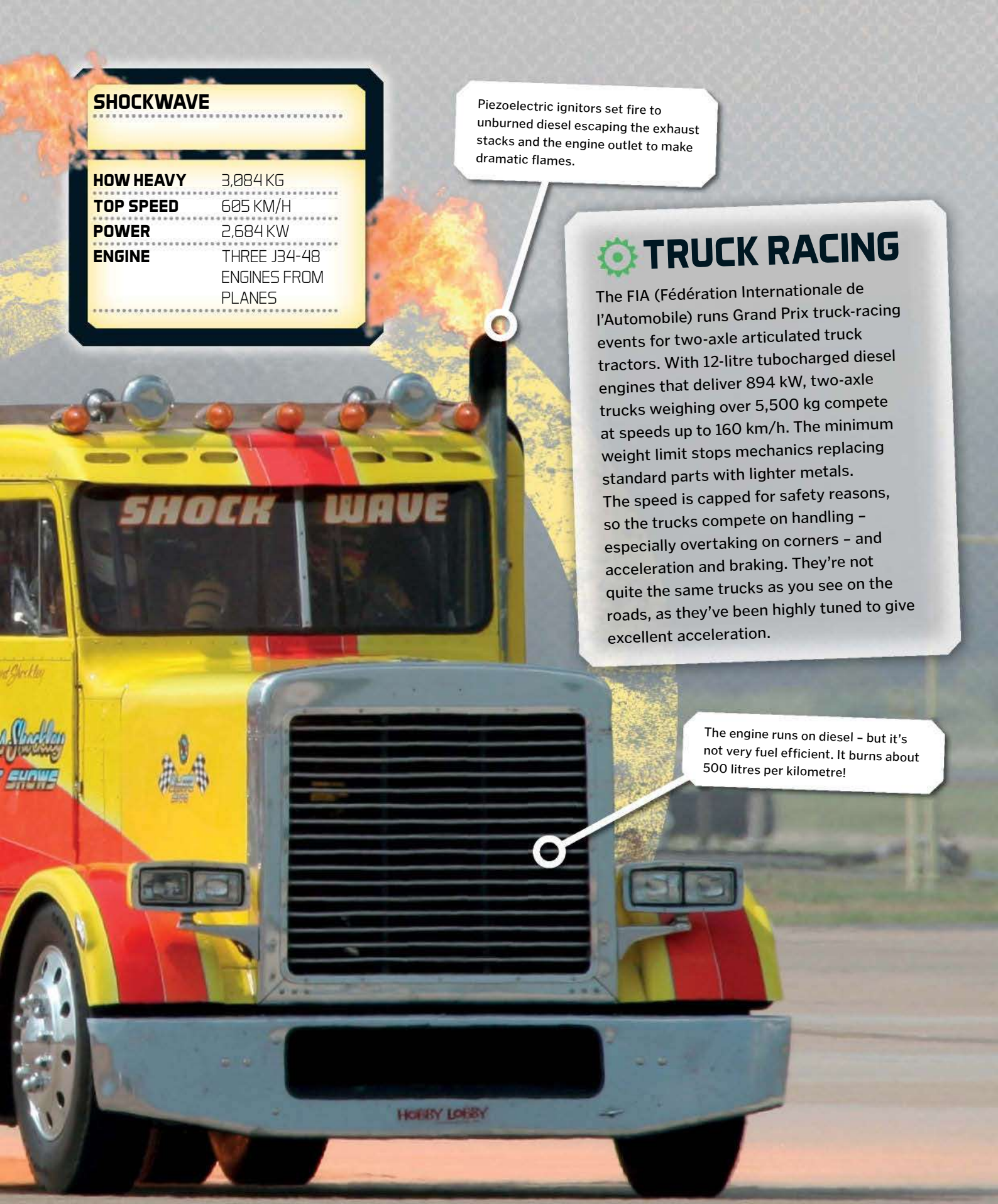
Shockwave has three Pratt & Whitney J34-48 engines normally used in planes. They produce as much thrust as the Space Shuttle, so even though Shockwave is heavy it's in danger of lifting. The engines are arranged in a pyramid, slightly tilted to help keep the truck on the ground.

Tyres each have 38.5 kg of tread shaved away to reduce the mass of the truck and prevent the tread ripping away at high speeds.

LEAN, MEAN AND GREEN

Running a truck like Shockwave takes a lot of fuel – but the Volvo Mean Green lets truck-lovers enjoy a less fuel-hungry ride. Mean Green is built from standard Volvo truck components, including a highly tuned D16 engine, but it also has an electric motor. A hybrid vehicle combines power from standard fuels such as diesel or petrol with power from another source – usually electricity, solar or wind power. The Mean Green uses diesel for most of its power, but nearly 10% comes from an electric motor. It can reach 236 km/h.

Mean Green is the fastest hybrid truck on the planet.



SHOCKWAVE

HOW HEAVY	3,084 KG
TOP SPEED	605 KM/H
POWER	2,684 KW
ENGINE	THREE J34-48 ENGINES FROM PLANES

Piezoelectric ignitors set fire to unburned diesel escaping the exhaust stacks and the engine outlet to make dramatic flames.

TRUCK RACING

The FIA (Fédération Internationale de l'Automobile) runs Grand Prix truck-racing events for two-axle articulated truck tractors. With 12-litre tubocharged diesel engines that deliver 894 kW, two-axle trucks weighing over 5,500 kg compete at speeds up to 160 km/h. The minimum weight limit stops mechanics replacing standard parts with lighter metals.

The speed is capped for safety reasons, so the trucks compete on handling – especially overtaking on corners – and acceleration and braking. They're not quite the same trucks as you see on the roads, as they've been highly tuned to give excellent acceleration.

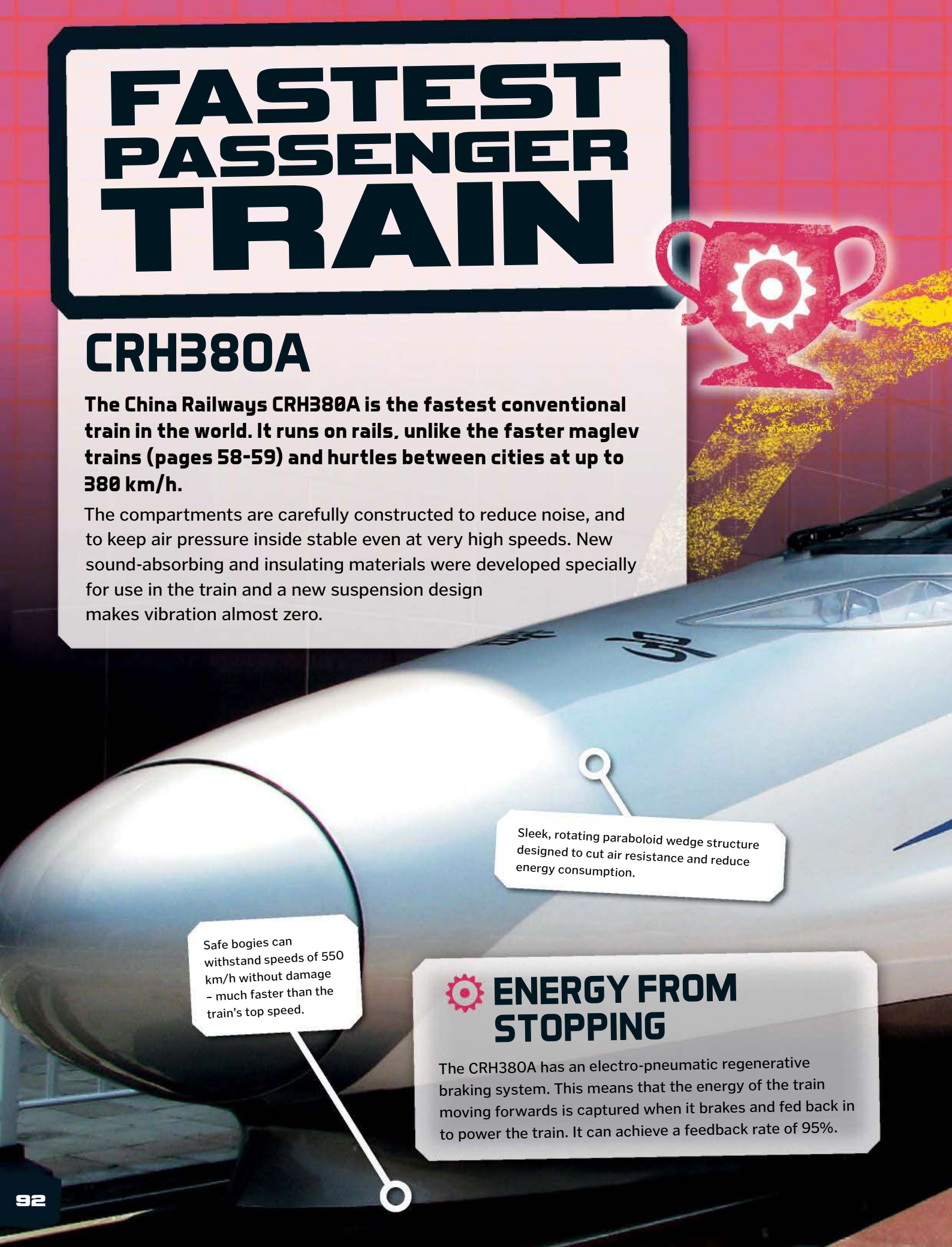
The engine runs on diesel – but it's not very fuel efficient. It burns about 500 litres per kilometre!

FASTEST PASSENGER TRAIN

CRH380A

The China Railways CRH380A is the fastest conventional train in the world. It runs on rails, unlike the faster maglev trains (pages 58-59) and hurtles between cities at up to 380 km/h.

The compartments are carefully constructed to reduce noise, and to keep air pressure inside stable even at very high speeds. New sound-absorbing and insulating materials were developed specially for use in the train and a new suspension design makes vibration almost zero.



Sleek, rotating paraboloid wedge structure designed to cut air resistance and reduce energy consumption.

Safe bogies can withstand speeds of 550 km/h without damage – much faster than the train's top speed.

ENERGY FROM STOPPING

The CRH380A has an electro-pneumatic regenerative braking system. This means that the energy of the train moving forwards is captured when it brakes and fed back in to power the train. It can achieve a feedback rate of 95%.

CRH380A

WHEN	2010
TOP SPEED	380 KM/H TOP OPERATING SPEED; 416.6 KM/H FASTEST EVER
ACCELERATION	0-380 KM/H IN 7 MINUTES
SIZE	203 M LONG
POWER	9,600 KW

Lightweight aluminium-alloy body that is highly pressurised to keep the pressure stable inside.

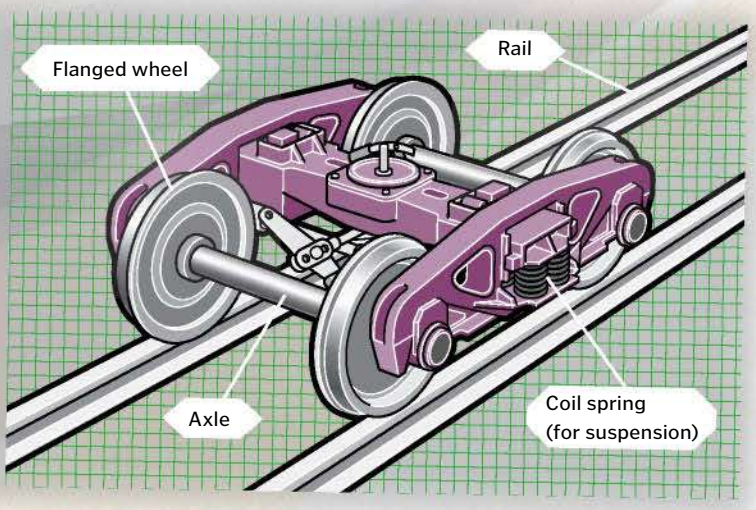
FASTER THAN A SPEEDING BULLET?

The Japanese bullet trains run at up to 300 km/h, connecting all the main cities in Japan. They run on special railway lines with only long, open curves and no tight corners so that the trains don't have to slow down.

There are nearly 2,400 km of high-speed track, making up the world's busiest high-speed rail network.

BOGIES

The body of a railway carriage is mounted on a bogie – a truck with special flanged wheels that fit onto a track. Because the raised part of the track fits into a groove in the wheels, it's hard for a train to be derailed. Suspension between the bogie and the carriage absorbs shock and vibration, making the ride more comfortable and protecting the carriage from damage.



MIGHTIEST MAGLEV

SHANGHAI MAGLEV

The fastest maglev train service runs from Shanghai Pudong airport to the centre of Pudong. Its top operational speed is 431 km/h - faster than a Formula 1 racing car. The journey of 30.5 km takes only seven minutes and 20 seconds.

Maglev is short for 'magnetic levitation'. Maglev trains have no wheels, but are guided and propelled using a system of magnets in the guideway and the underside of the train. The train has three different systems: one for guidance, one for levitation and one for propulsion.

Inside the train, the ride is smooth and almost silent.

FASTEST EVER

The fastest speed ever recorded for any railed vehicle is 581 km/h, reached by the Japanese MLX01 maglev train. It uses wheels for support until it reaches a speed of 150 km/h because at low speeds the magnetic field is not strong enough for levitation. For its record-breaking run, it was configured as a three-car train, but can have a maximum of five cars.

The MLX01 running on Japan's Yamanash Maglev test line.

SHANGHAI MAGLEV

WHEN	2004
TOP SPEED	431 KM/H
ACCELERATION	0-350 KM/H IN 2 MINUTES

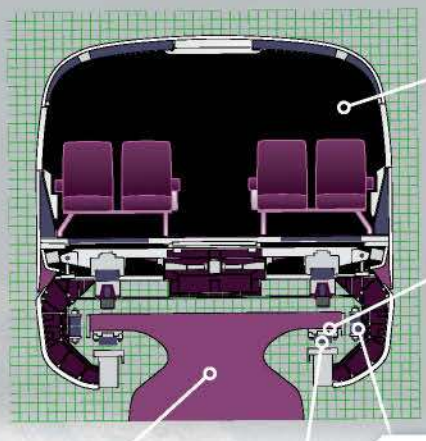
PUSHED AND PULLED

Magnetised coils of metal are embedded in the walls of the guideways. The polarity of the coils is switched very quickly to interact with magnets under the train. North and south poles attract each other but like poles (north/north and south/south) repel each other.

By alternately attracting and repelling magnets under the train, the train is both pushed and pulled forwards.

FLOATING

Strong magnets powered by electricity lift the train so that it floats a few centimetres above the guideway. With no moving parts in contact with the rails, there's no friction so the trains can go very fast. There is also no wear-and-tear so the trains last a long time.



Train floats above the guideway, propelled and guided by strong magnetic fields.

Guideway raised above the ground and supported by giant columns every 25 m along the track.

FASTEST ROLLERCOASTER

FORMULA ROSSA

The fastest rollercoaster in the world is the Formula Rossa at Ferrari World theme park in Abu Dhabi - by a long way! It's 40km/h faster than previous rollercoasters, taking just 4.9 seconds to get from 0 to its top speed of 240 km/h.

The train is launched with as much force as the catapult on an aircraft carrier launches jets. The feeling of being in the train is as close to being in a Formula 1 car as possible. Riders have to wear goggles like those worn by skydivers to protect their eyes from sand, dust and insects.

The speed and acceleration on the ride are the same as in a Ferrari Formula 1 race car – passengers feel 4.8 times the force of gravity.

2.09 km of track is covered in a run that takes only 92 seconds.

HYDRAULIC POWER

Rollercoasters use hydraulic launchers to blast the trains down the track. Hydraulic fluid is pumped into accumulators that have two compartments separated by a piston. As hydraulic fluid is pumped into one compartment, gas in the other is compressed. At launch, the accumulators simultaneously release their stored power to drive 16 or 32 hydraulic motors. These spin a winch that rewinds a cable connected to a catch-car under the train. The catch-car moves along a groove in the launch track. A launch can have a peak power of 15,000 kW – as much as nearly 120 family cars!

FORMULA ROSSA

WHEN	2010
TOP SPEED	240 KM/H
ACCELERATION	0-100 KM/H IN 2 SECONDS
SIZE	2.07 KM TRACK

The train is launched by hydraulic motors, then immediately climbs a 53 m hill, when it's then slowed down by magnetic brakes.

UPSIDE DOWN AND INSIDE OUT

The Formula Rossa focuses on speed, but the Colossus rollercoaster at Thorpe Park, England, concentrates on twists and turns. It has more inversions – when passengers are upside-down – than any other rollercoaster in the world, with a vertical loop, a cobra roll, two corkscrews and five heartline twists.

Record-breaking ups and downs on the Colossus.

GOING DOWN!

The rollercoaster with the biggest drop is Kingda Ka at Six Great Flags Adventure in Jackson, USA. The coaster cars are launched at such force they reach a speed of 206 km/h in three seconds.

At the end of the launch track they whizz up a 'top hat' tower 139 m tall and then plummet straight down for 127 m! The whole ride takes only 28 seconds.

QUICKEST WIND-POWERED VEHICLE

ECOTRICITY GREENBIRD

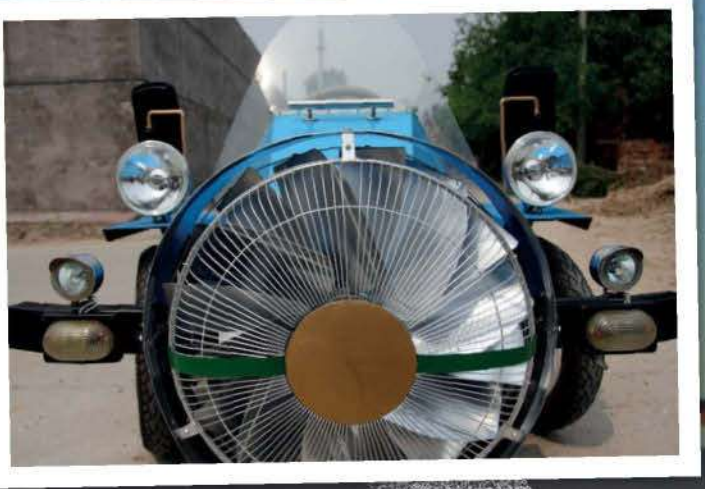
It's not really a car and it's not really a boat - the Ecotricity Greenbird is a land yacht. It's powered by wind, which is caught in its sails, and it's driven over the land just like a yatch is driven over water. It broke the world record for land yachts by travelling at 203 km/h in Nevada, USA, in 2009.

The key to its success is its combination of aircraft and Formula 1 design elements. Just as the force of wind under an aircraft wing keeps the plane in the air, so the force of wind behind the Greenbird's sail drives it forward. It has wheels in the nose, beneath the tail and under the outrigger.

The position of the sail is controlled by a tail, attached to it with a rod. The wind pushes on the tail and the movement is conveyed from the rod to the sail.

TURN AROUND

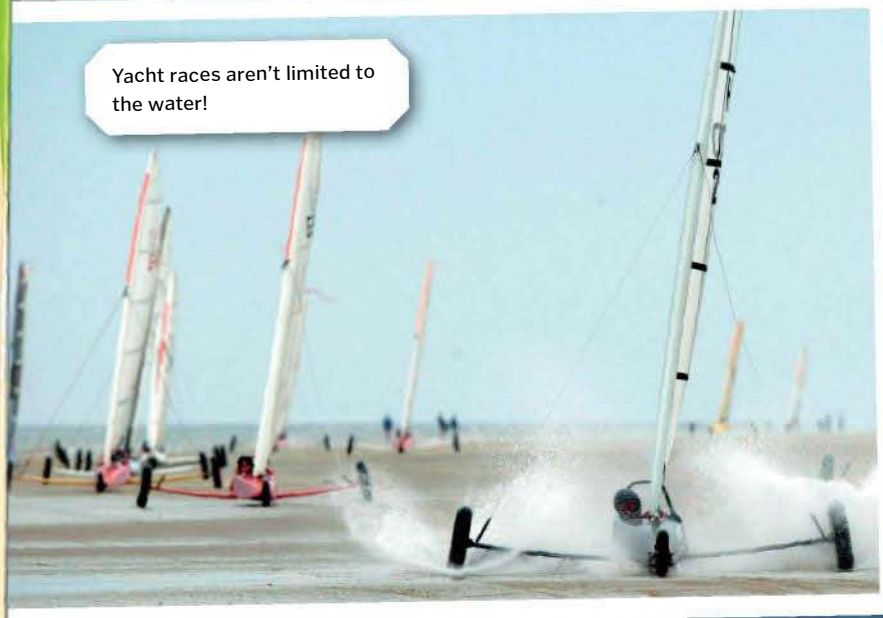
Another way of harnessing wind power uses the wind to drive a turbine rather than push on a sail. It uses the same principle as a windmill or wind turbine, but instead of powering a mill or a generator, it drives a vehicle.



An outrigger on a long arm prevents the Greenbird being overturned by the force of wind against the sail.

RACING BOATS ON LAND

Races for land yachts use the wind to power a vehicle that looks more like a boat than Greenbird. These land yachts have flexible sails and no outrigger. The faster the boat, the wider the wheel base needed to stop the yacht tipping over.



Yacht races aren't limited to the water!

GONE WITH THE WIND

The Greenbird's streamlined shape and efficient design mean it can run faster than the wind that is blowing it – up to five times as fast as the wind speed, in fact. The sail must be angled to keep the wind on the right side, pushing the vehicle forwards. An adapted version of the Greenbird can run on ice. The ice version has a different nose and skates instead of wheels.

ECOTRICITY GREENBIRD

WHEN	2009
HOW HEAVY	600 KG
TOP SPEED	203 KM/H
ENGINE	NONE

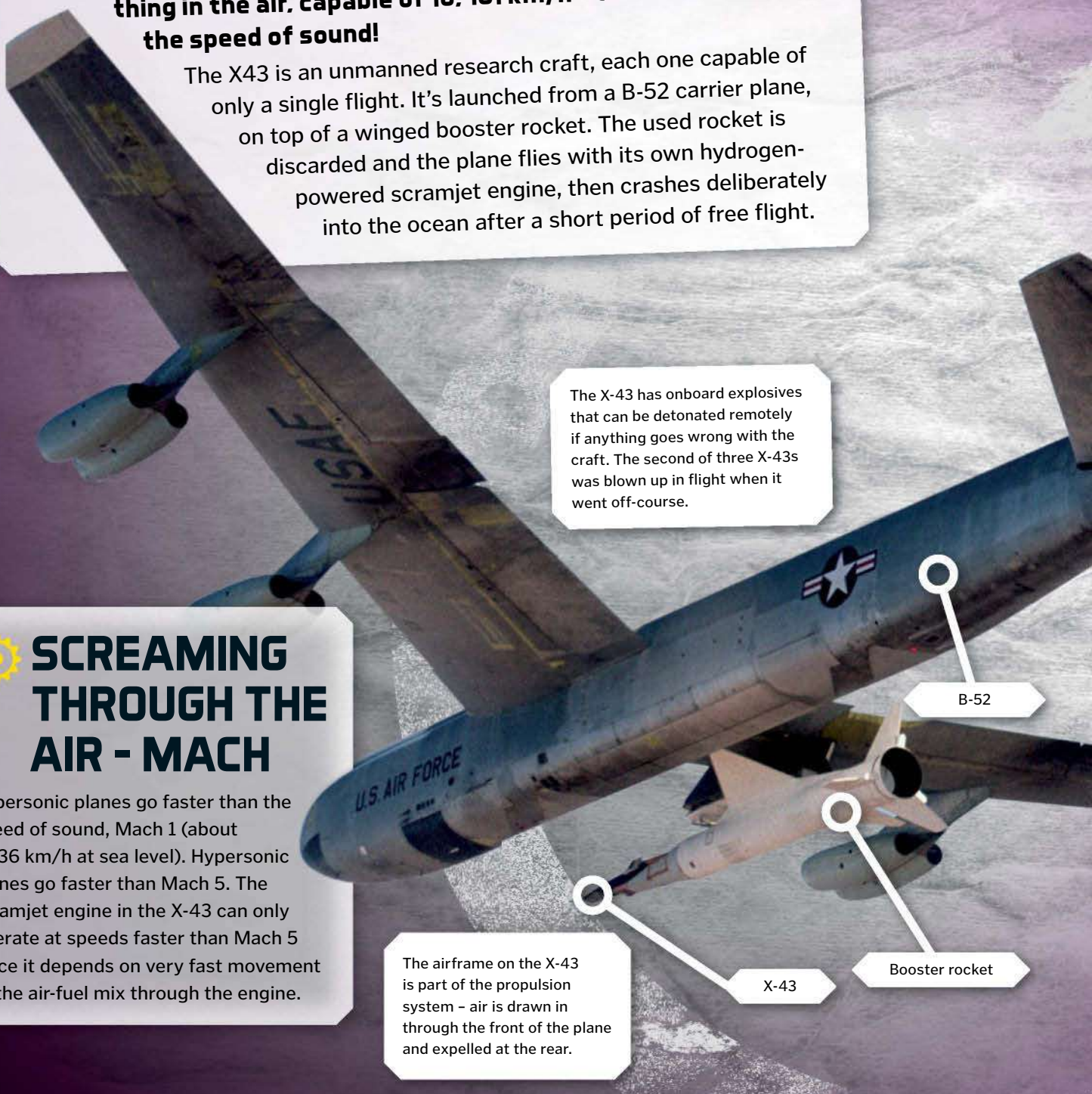
It's made entirely from carbon-fibre composite – the only metal is in the wheel units and wing bearings.

FASTEST FLIERS

NASA X-43A

NASA's hypersonic experimental X43 aircraft is the fastest thing in the air, capable of 10,461 km/h - that's ten times the speed of sound!

The X43 is an unmanned research craft, each one capable of only a single flight. It's launched from a B-52 carrier plane, on top of a winged booster rocket. The used rocket is discarded and the plane flies with its own hydrogen-powered scramjet engine, then crashes deliberately into the ocean after a short period of free flight.



The X-43 has onboard explosives that can be detonated remotely if anything goes wrong with the craft. The second of three X-43s was blown up in flight when it went off-course.

The airframe on the X-43 is part of the propulsion system – air is drawn in through the front of the plane and expelled at the rear.

SCREAMING THROUGH THE AIR - MACH

Supersonic planes go faster than the speed of sound, Mach 1 (about 1,236 km/h at sea level). Hypersonic planes go faster than Mach 5. The scramjet engine in the X-43 can only operate at speeds faster than Mach 5 since it depends on very fast movement of the air-fuel mix through the engine.

ASTRO-PILOTS

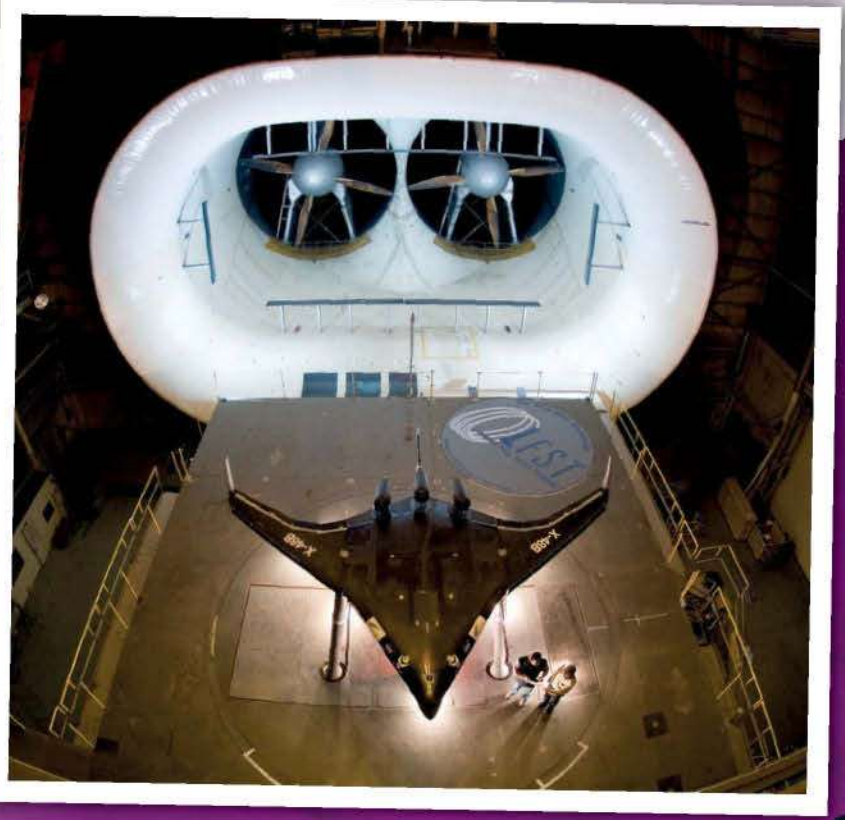
The fastest piloted plane was the North American X-15, which reached 7,274 km/h in 1967. It also holds the record for the highest altitude for a manned plane, at 107.8 km in 1963. At this altitude, it was touching the edge of space, considered to be at 100 km!

Pilots flying the X-15 at altitudes of 80+ km count as astronauts!

WHY CRASH EXPERIMENTAL PLANES?

Most planes and engines are tested on the ground in wind tunnels. The movement of air around and through firstly models and later full-scale planes and parts is tracked and analysed by computer without the need for a flight. But wind tunnels can't reproduce the effects of hypersonic flight. The only way to test engines and plane designs at such speeds is to make them and fly them.

Carbon thermal protection material and circulating water protect the metal on the X-43 from melting as friction causes temperatures to reach nearly 2,000° Celsius.



NASA X-43A

WHEN	2004
HOW HEAVY	1300 KG
TOP SPEED	10,461 KM/H
ALTITUDE	33,528 M
SIZE	3.7 M LONG

FASTEST RACER ON WATER

SPIRIT OF AUSTRALIA

The fastest thing on the water is a speed-boat built of wood and fibreglass in an Australian backyard. Ken Warby built Spirit of Australia in the 1970s and then piloted it himself, setting a world speed record of 511.11 km/h in 1978.

Spirit of Australia is powered by a Westinghouse J34 jet engine, originally designed for use in jet fighters and other planes in the late 1940s. Warby bought it secondhand at auction for $69.

FLOATING ON AIR

The fastest boats have two wide sponsons, a bit like fat skis, and a space between them. The boat glides over the water on the sponsons, with air rushing through the space and giving the boat lift. At high speed, the front lifts up, and just part of the sponson and the rudder stay in contact with the water.

IN CONTROL

Racing powerboats are used on lakes and rivers, but for speedboats used on the sea, navigation is important. The speedboat controls include a digital display of a map, showing the position of the boat. There aren't many landmarks at sea, so this is vital.

POWERBOAT RACING

Formula 1 powerboat racing is very like F1 car racing except that it's on water. The powerboats are optimised for speed, with powerful jet engines and streamlined shapes. They are tunnel-hull catamarans, with only a few centimetres of the boat in contact with the water at top speeds. F1 powerboats are super-light – 390 kg, of which around a third is the engine. They can reach top speeds of around 250 km/h.

The aerodynamic shape cuts drag. The boat is not built for turning, though – it only goes in a straight line!

The frame is made of spruce and oregon, with plywood and fibreglass covering, making it light and strong.

Spirit of Australia is a three-point hydroplane – the only parts to touch the water at top speed are the two front sponsons and the rudder at the back.

SPIRIT OF AUSTRALIA

WHEN	1978
HOW HEAVY	1,500 KG
TOP SPEED	511.11 KM/H
SIZE	8.22 M LONG
COST	$10,000
POWER	4,474 KW; 1,587 KG THRUST
ENGINE	WESTINGHOUSE J34

ROUND-THE-WORLD RECORD BREAKER

EARTHRACE

The record for the fastest motorized boat to go all round the world is held by the strange-looking vessel Earthrace. In 2008, it circled the globe in just 60 days, 23 hours and 49 minutes.

The trimaran ran on bio-diesel and had other ecological features such as vegetable oil lubricants, bilge-water filters and composite materials made from hemp. It was used in anti-whaling operations, but sank in 2010 after colliding with a whaling support ship.

Twin propellors are mounted under the main hull and rudders are on the outriggers.

The trimaran design makes it harder to capsize and means it can go into shallower water than a monohull as it doesn't need a deep, weighted keel.

BIGGEST UNDER THE SUN

The Tûranor PlanetSolar became the first electric solar-powered vehicle to circle the globe in 2012 – it took 584 days. Its solar panels are capable of producing 93 kW of electricity to drive two motors. It can reach a maximum speed of 26 km/h, but its cruising speed is 13.9 km/h. At 31 m long and with displacement of 85,000 kg it can carry 200 people.

The Tûranor PlanetSolar has 500 m2 of solar panels with 38,000 photovoltaic cells.

The vessel has space for 200 passengers.

EARTHRACE

WHEN	2008
TOP SPEED	59.3 KM/H
SIZE	24 M LONG; 7 M WIDE
COST	$2.5 MILLION
POWER	800 KW

A trimaran has a main hull and two outriggers attached to the main body of the boat by struts. Trimarans were first made by Polynesian islanders 4,000 years ago.

UNDERWATER BOAT

Earthrace was fully submersible. It could slice through 15-metre high waves and dive 7 metres underwater. The hull was made of a composite of carbon fibre and Kevlar and coated with special, non-toxic, anti-fouling paint that prevents algae and marine creatures growing on it.

ROUND THE WORLD

Boats sailing around the world have a limited choice of routes. Unless they want to make long detours, they have to go through the Panama Canal that runs between North and South America, and through the Suez Canal in Egypt that joins the Red Sea and the Mediterranean.

QUICKEST ICE EXPLORER

BIO-INSPIRED ICE VEHICLE

You might have slid over snow on a sledge - but imagine whizzing at 130 km/h over the polar ice. The Bio-Inspired Ice Vehicle (BIV) skates over the snow on skids that look like fat skis. It's light enough to be dragged over the huge waves of icy snow found in some parts of Antarctica.

The BIV is not only the fastest ice-going vehicle – it was also used in 2012 in a record-breaking crossing of Antarctica, only the third-ever land crossing. It's also the first biofuel-powered vehicle ever to reach the South Pole.

Extremely low temperatures are punishing for mechanical equipment, so the BIV has as few moving parts as possible to help avoid problems.

Three-blade, variable-pitched propellor is powered by a Rotax 914 aircraft engine, run on biodiesel. The Rotax is well suited to high altitudes and low temperatures.

BIO-INSPIRED ICE VEHICLE	
WHEN	2012
HOW HEAVY	700 KG
TOP SPEED	135 KM/H
SIZE	4.5 M LONG

MAKING TRACKS

Polar vehicles usually have tracks rather than skis. The tracks make it easier to go uphill and over difficult ground, but make the vehicles much heavier as they need a more powerful motor.

SKIDOO!

Snowmobiles have a track at the back and skis at the front. Most have a four-stroke engine producing 110 kW or more, and tracks made of Kevlar. Some are used as emergency vehicles, and by people who work in the snow, such as reindeer herders. Others are sports vehicles. Racing snowmobiles can reach speeds of 240 km/h and dragster snowmobiles up to 320 km/h.

Snowmobiles can be raced on snow, but also on grass.

SAFETY FIRST

The BIV goes ahead of two science support vehicles, finding a safe route. It uses cameras and ground-penetrating radar to investigate the ground and highly sensitive GPS systems to track its location. It also has sensors to monitor the driver's body so that it can pick up any problems such as the start of hypothermia. The information is sent wirelessly to a computer on one of the science support vehicles for instant analysis.

Three skis with independent suspension for gliding over the snow, and a spiked snow brake to stop safely.

HOW IT WORKS

EXTREME ENGINEERING

HOW IT WORKS BOOK OF MEGA MACHINES


KAIKO
KAIKO


130


118
Redbull
TOTAL


134

BIGGEST BORER

BERTHA

Tunnels are drilled by massive 'moles' called Tunnel Boring Machines (TBMs) - and the most massive of all is Bertha, built by Hitachi Zosen Corporation in Japan.

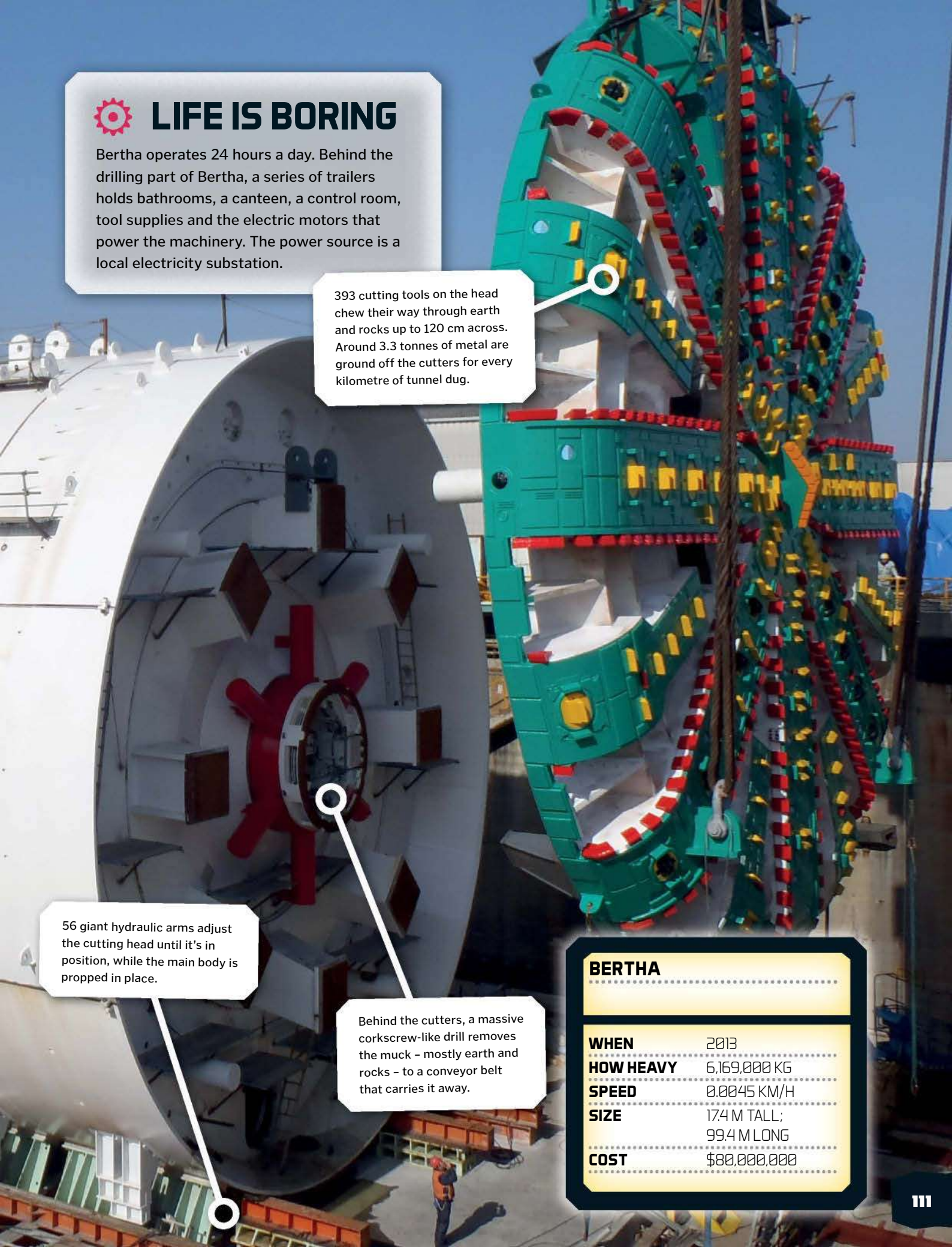
As Bertha moves along, vast cutting tools grind away at the earth in front of her. The muck is carried away, back along Bertha's length, to be dumped. As she clears a path, Bertha inches forwards very slowly. She moves at only 7.5 cm per minute – that's 756 m per week!

LASER GUIDANCE SYSTEM

Bertha is guided by laser. The laser is projected from behind the TBM and received by a guidance system at the front, precisely set to the planned path for the tunnel. The operator steers Bertha, adjusting the hydraulic arms with each push forward to align the machine correctly. Bertha should be able to get within 15 cm of her planned finishing point.

CUT TO SIZE

The cutting head at the front of Bertha is more than 17 m across and stands as tall as a six-storey building. That's just the very front of the machine – in total, Bertha is almost 100 m long. Bertha is shipped in 41 pieces. These are lowered by crane into an 80-m deep launch pit and put together underground.



LIFE IS BORING

Bertha operates 24 hours a day. Behind the drilling part of Bertha, a series of trailers holds bathrooms, a canteen, a control room, tool supplies and the electric motors that power the machinery. The power source is a local electricity substation.

393 cutting tools on the head chew their way through earth and rocks up to 120 cm across. Around 3.3 tonnes of metal are ground off the cutters for every kilometre of tunnel dug.

56 giant hydraulic arms adjust the cutting head until it's in position, while the main body is propped in place.

Behind the cutters, a massive corkscrew-like drill removes the muck – mostly earth and rocks – to a conveyor belt that carries it away.

BERTHA

WHEN	2013
HOW HEAVY	6,169,000 KG
SPEED	0.0045 KM/H
SIZE	17.4 M TALL; 99.4 M LONG
COST	$80,000,000

TALLEST MOBILE CRANE

LIEBHERR LTM 11200-9.1

The tallest crane in the world is also the strongest. The Liebherr LTM 11200-9.1 could lift twelve blue whales at once. The boom uses hydraulics to extend up to 100 m. Unextended, it's as long as the truck and has to be transported separately between work sites.

The crane is used to lift heavy loads. One task it's particularly well suited to is installing and repairing huge wind turbines. These are too tall for most cranes to deal with, being about 100 m high.

Thick steel cables running up and over the boom hold the weight of the load.

The telescopic boom extends from 18.3 to 100 m using a hydraulic system. It takes nearly 13 minutes to extend from 50 m to its full 100 m.

The crane mechanism has its own six-cylinder turbodiesel engine that can deliver 240 kW.

LIEBHERR LTM 11200-9.1

WHEN	2007
WEIGHT	96,000 KG
TOP SPEED	75 KM/H
SIZE	20 M LONG; TALLEST REACH 100 M
POWER	500 KW

A Boeing 747 Chinook helicopter lifts a vehicle.

HELICOPTER HELP

Sometimes a load needs to be lifted higher than the tallest cranes can reach, or moved into a restricted space where a crane can't go. Then helicopters can be used instead, lifting and delivering a load.

DON'T FALL!

Huge bracing legs, called outriggers, extend sideways to create a wide, stable base for the superstructure. But this still would not be enough when the crane is holding a heavy load. It uses counterweights to prevent the load and the boom being heavier than the truck, and so tipping it over. It can take counterweights up to 202,000 kg.

TALLER STILL

The tower cranes used to build very tall buildings are even taller than the Liebherr LTM 11200-9.1, but they can't move around. They are built on a concrete base and have to be constructed on site. A tower crane has a tall tower, then a horizontal jib that carrries the load at one end and a counterweight – usually concrete slabs – at the other end.

LONGEST CABLE CAR

TATEV AERIAL TRAMWAY

The longest cable car ride in the world is Tatev aerial tramway in Armenia. It spans the Vorotan River Gorge, linking the village of Halizor and the medieval Tatev Monastery - a distance of 5,752 m. It can travel at 37 km/h.

The system has two cars that travel along cables suspended over the ground to carry passengers up the mountain. There are three support towers between the terminals. At its highest the tramway is 300 m above the ground. The two cars can each carry 25 passengers. As one car goes up, the other comes down.

The cars have no engines, but hang from a propulsion cable by a grip and are pulled along with the cable.

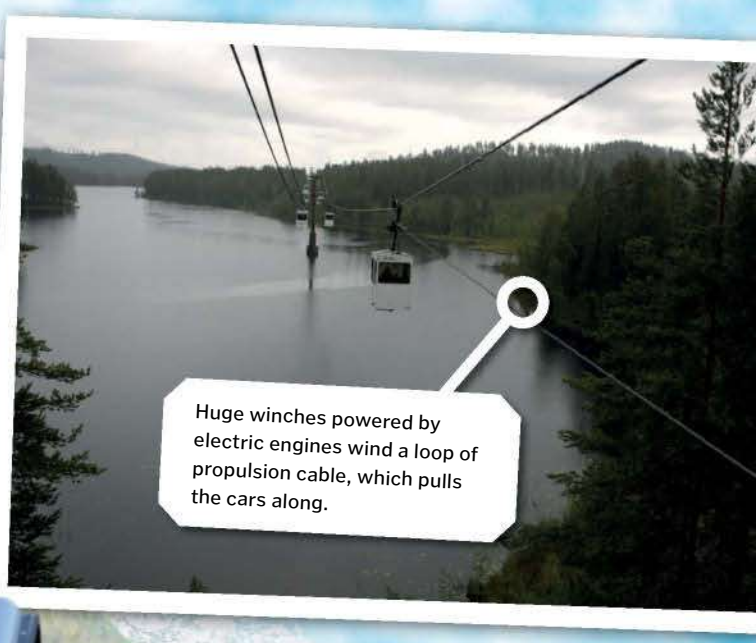
The cables run in straight lines as the cars can't turn corners – they can't decouple from the propulsion wire to go round a wheel in the way gondola ski lifts turn corners.

SCARIEST

Perhaps the scariest cable car ride in the world is at Heaven's Gate Mountain (Tianmen Chan) in China. Strictly speaking, it's not a cable car but a gondola. It soars above a breathtaking mountain gorge travelling up a height of 1,279 m over a run of 7,455 m and at times reaching an angle of 38 degrees. Swaying above the forest in a tiny metal capsule – that's got to be scary.

EVEN LONGER

Norsjö aerial tramway (right) is a 13.2 km aerial tramway in Sweden, but no longer runs regularly. It was built in the 1940s to move metal ore around a mining district. The cabins can each hold four people. The cars travel at a top speed of 10 km/h and take one hour and 45 minutes to complete the journey.



Huge winches powered by electric engines wind a loop of propulsion cable, which pulls the cars along.

QUICK ESCAPE!

Rocket launch sites often have cable car escape systems that can take launch staff and astronauts away from a launch that is going wrong. The cable car takes them down from the launch tower to a protective shelter.

TATEV AERIAL TRAMWAY

WHEN	2010
TOP SPEED	37 KM/H
SIZE	5,752 M

LONGEST TRAIN JOURNEY

TRANS-SIBERIAN RAILWAY

The longest single train journey in the world, without changing trains, is the Trans-Siberan Railway's service from Moscow in Russia to P'yongyang in North Korea. The weekly train takes 210 hours (nine days) to make the trip, a distance of 10,175 km.

Both passenger and freight trains run on the Trans-Siberian routes. Some freight trains are over a kilometre long, with 71 wagons and weighing 6,000 tonnes. Trains have 24 crew changes and four changes of locomotive on the journey.

Trains are designed to operate in temperatures of -40°c to +40°C.

SUPER-DUPER OPTION

Trips on the Trans-Siberian route are generally a few hundred pounds, but the special Golden Eagle from Moscow to Beijing costs up to £18,695! The train is pulled by the only remaining steam locomotive in Russia, and offers private suites with bathrooms, luxury restaurants and comfortable lounges.

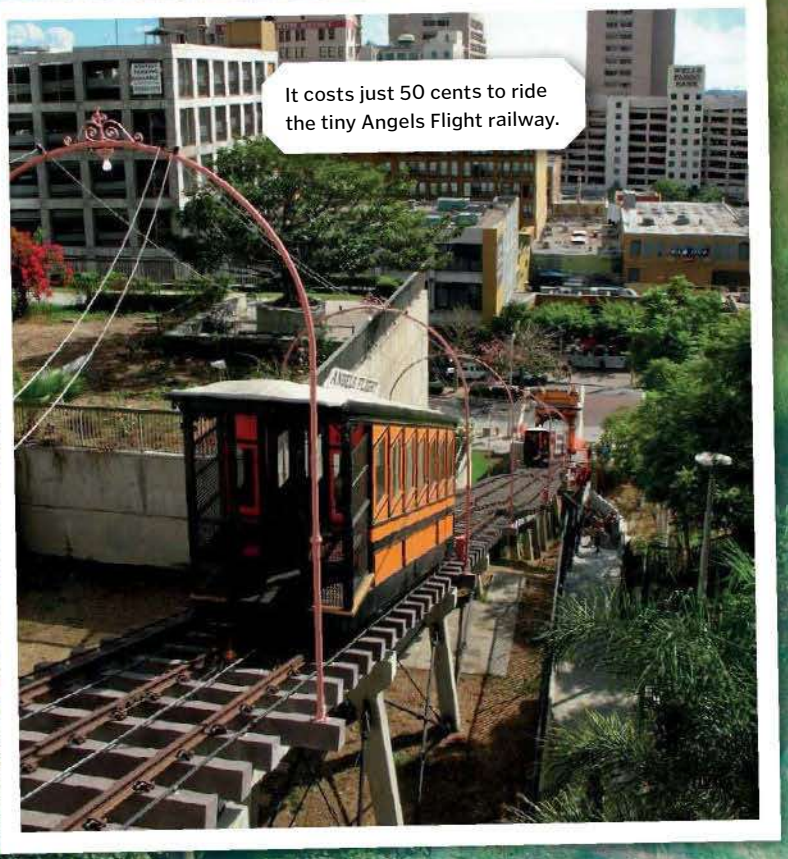
There are other luxury trains, too. The Venice-Simplon Orient Express that runs between Paris in France and Venice, Italy, has polished wood panelling, marble bathrooms and extravagant restaurants.

TRANS-SIBERIAN RAILWAY

WHEN	STARTED 1891
TOP SPEED	120 KM/H
LENGTH	10,175 KM

SHORTEST TRIP

The shortest public railway line is 95 m long. Called Angels Flight, it carries passengers up a steep hill in the city of Los Angeles, USA. The Trans-Siberian route from Moscow to P'yongyang is more than 107,000 times as far!



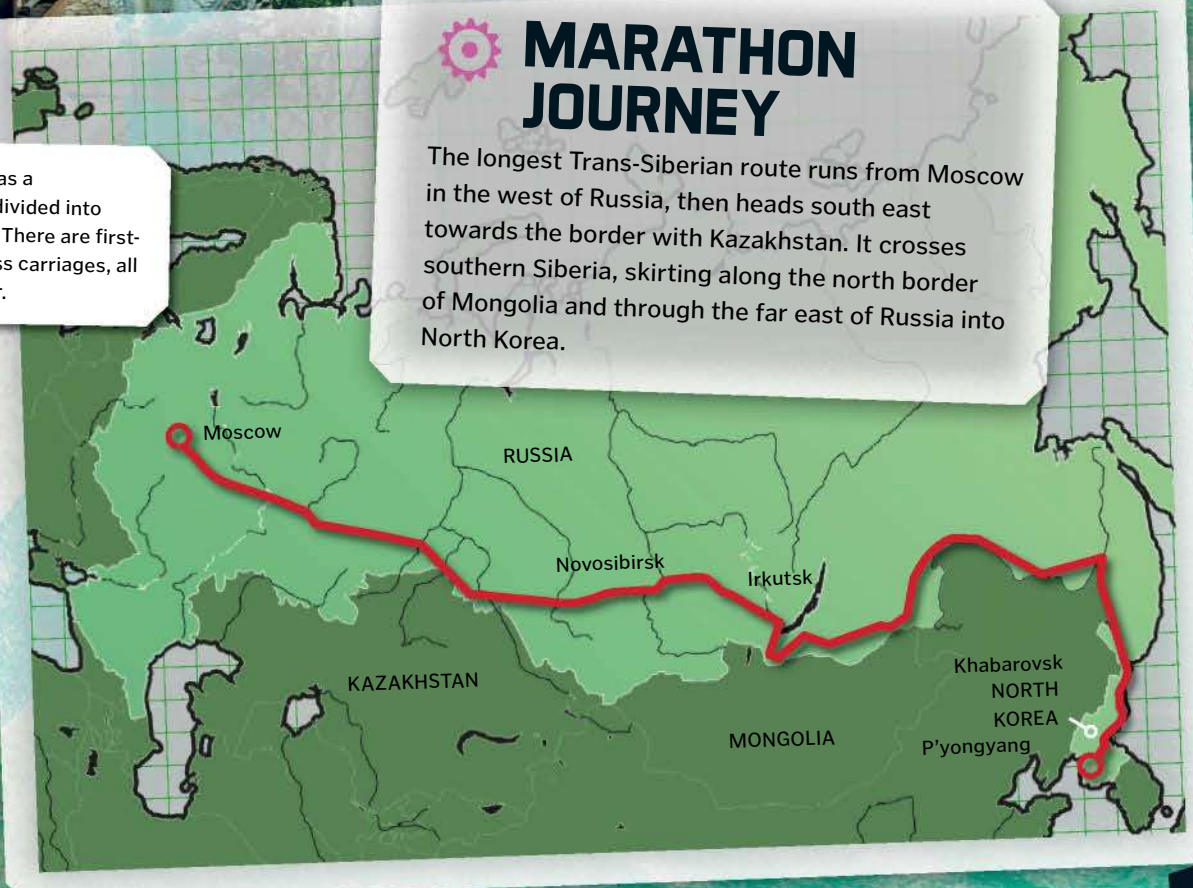
It costs just 50 cents to ride the tiny Angels Flight railway.

Electric train with overhead pantograph.

Each carriage has a corridor and is divided into compartments. There are first- and second-class carriages, all heated in winter.

MARATHON JOURNEY

The longest Trans-Siberian route runs from Moscow in the west of Russia, then heads south east towards the border with Kazakhstan. It crosses southern Siberia, skirting along the north border of Mongolia and through the far east of Russia into North Korea.



RECORD-BREAKING VEHICLES

RECORD BREAKERS

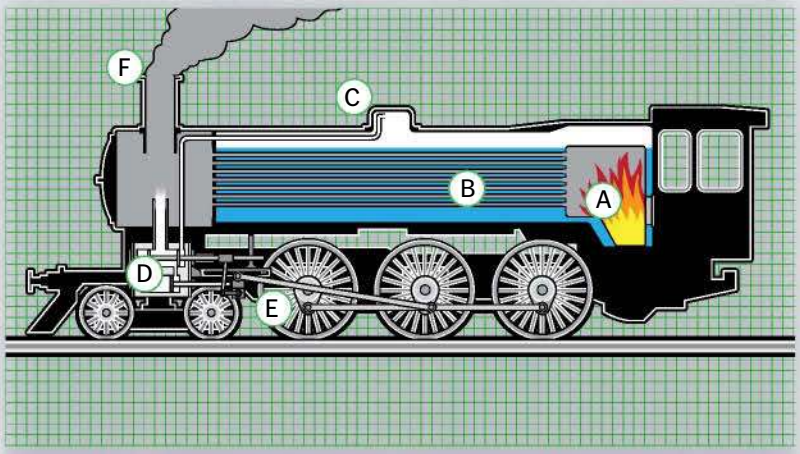
For thousands of years, no one could travel faster than a horse could gallop. The fastest vehicles were carts, carriages and sledges pulled by animals. It took months to cross a continent.

That was before we had engines. Then, around 250 years ago, a revolution began. A revolution that has given us trains, cars, planes, motorbikes, helicopters, submarines, dumper trucks, rollercoasters and much more.

The Zefiro 380 maglev can reach an amaxing maximum speed of 380 km/h.

ON THE MOVE

The very first powered vehicles were trains. They worked by burning coal to heat water, turning it to steam. The steam was used at high pressure to drive an engine, and that turned the wheels of the train. Later, trains were powered by diesel and then electricity. Now, super-fast electric trains travel at over 300 km/h, and maglev trains go even faster – over 400 km/h.



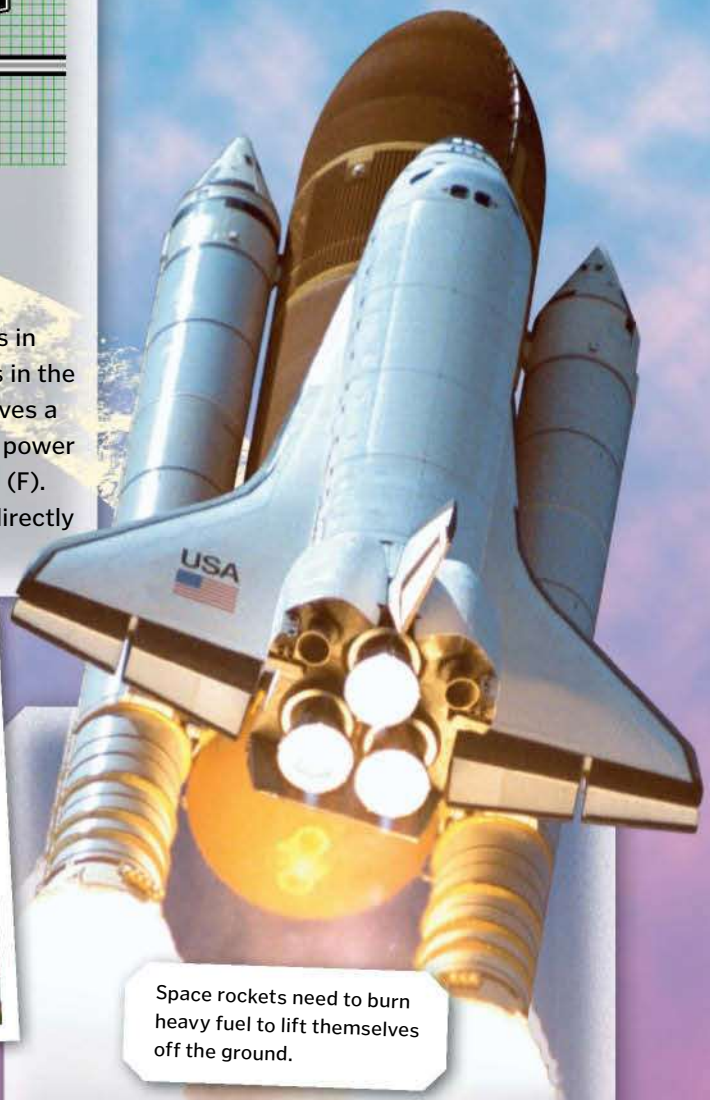
HOW A STEAM TRAIN WORKED

Hot gases from burning fuel in the firebox (A) go through tubes in the boiler (B). Water in the boiler turns to steam which collects in the steam dome (C). Steam is sent to the cylinders (D) where it drives a piston. The piston drives a connecting rod (E) which transmits power to the wheels. Waste steam and gases leave through the stack (F). Some of the steam will condense, and the gases go out here (directly from the pipes that have carried them through the boiler).

Formula 1 cars like this one are streamlined for maximum speed.

ENGINES FOR EVERYONE

A train carries lots of people – but you can only go where the train is going. The invention of the internal combustion engine made personal transport possible. Cars and motorbikes used this type of engine. Power comes from burning a liquid fuel, such as petrol or diesel. The fastest cars can travel at 400 km/h.



Space rockets need to burn heavy fuel to lift themselves off the ground.

LIFT OFF

The fastest cars have to be specially designed so that they don't lift off the ground. Engines can also take us off the ground deliberately. Fast, powerful planes use jet engines. As the engine burns fuel, waste gases pour from the back of the engine, creating a force which pushes the vehicle forwards. Space rockets work in the same way.

BIGGEST AND SMALLEST ENGINES

MONSTER MACHINE

Engine-powered vehicles range from massive supertankers to tiny collapsible motorbikes, from superfast rockets to giant earthmoving machines that crawl across the land.

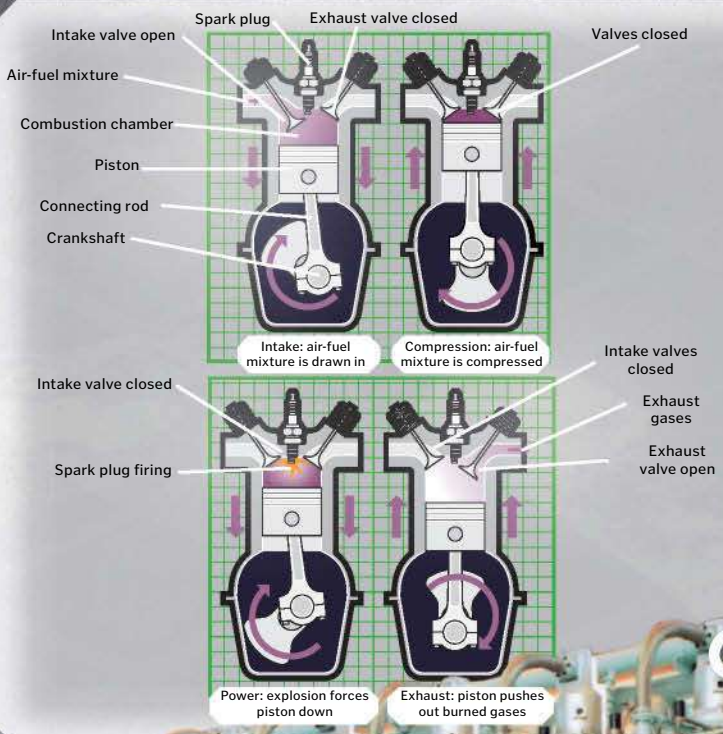
The biggest diesel engines in the world power supertankers – huge ships that carry oil or freight. The Wärtsilä-Sulzer RTA96-C is a turbocharged two-stroke diesel engine, used in container ships. The biggest, 14-cylinder version is 13.5 m high, 27.3 m long, weighs over 2,300 tonnes (2,300,000 kg), and produces 80,080 kW of power.

SUPER POWERS

Concern about the impact on the environment of burning fossil fuels has led engineers to explore other power sources, too. Some vehicles are driven by electricity and some by solar power (from sunlight), wind power, hydrogen cells or biofuels – fuels made from waste plant and food matter.

The Pratt & Whitney F100 is a monster aircraft engine.

A ladder is needed to scale the engine, which is the size of a three-storey building.



HOW CAR ENGINES WORK

Most cars and motorbikes use internal combustion engines. These create tiny explosions in an enclosed space. A fuel, such as petrol, is mixed with air and compressed in a chamber. A spark sets fire to the fuel. It burns explosively, pushing the piston at one end of the combustion chamber down. The movement of the piston is used to turn a crank. The piston goes up and down rapidly as the engine fires again and again, drawing in more fuel and air and setting light to it each time.

14 cylinders contain powerful pistons whose pumping motion is eventually translated into the movement of the ship.

Walkways surround the enormous engine to provide safe access for engineers.

MICRO MACHINE

The smallest vehicle engines are found in tiny, unmanned vehicles used for surveillance. Some of these crawl over the ground and others are mini-planes or helicopter-style drones. The tiniest are battery-powered. The Indian Tato Nano car has the smallest production petrol engine at 624 cc. It can drive the Nano at up to 105 kM/h.

MOST AMPHIBIOUS VEHICLE

WATERCAR PYTHON

If you've ever wished you could just drive across a lake or river, the WaterCar Python is what you need. It's an awesome amphibious vehicle - a car on land and a speedboat on water!

Each Python is hand-built and the new owner can choose the Corvette engine they want. There is a Dominator jet to provide power on the water. The interior of the boat/car is styled like a powerboat, with captains' seats in the front and a bench seat in the back.

WATERCAR PYTHON	
HOW HEAVY	1,723 KG
TOP SPEED	96.5 KM/H ON WATER; 201 KM/H ON LAND
ACCELERATION	0-95 KM/H IN 4.5 SECONDS
SIZE	6.25 M LONG
COST	$200,000-$220,000

A rotor and jet are used to move the Python when it is in the water, in boat mode. On land, it uses a normal engine and wheels.

The two doors have a perfect seal so that they never let in water.

WATER SKIS WITH ENGINES

A jetski is a personal amphibious vehicle that's a cross between a powerboat and motorbike. The Kawasaki Ultra 300X is a sports jetski with a 1,500 cc supercharged engine. It can deliver 221 kW of power that a jet pump turns into super propulsion.

The compact Phibian covers distance at speed.

EMERGENCY AMPHIBIANS

The Gibbs Phibian is an amphibious search and rescue vehicle. The carbon-fibre vehicle can travel at 48 km/h over water.

It changes between land and water use in under ten seconds, with the wheels retracting to reduce drag and the dual jet-propulsion engine taking over. The Phibian is designed for use in police work and in response to natural disasters such as floods and tsunami.

LIKE A DUKW IN WATER

The DUKW was originally designed as a military vehicle. Renovated DUKWs are now used for tourist trips, as rescue vehicles and sometimes by fishermen. It was the first vehicle to allow the driver to change the tyre pressure from the cab, making it easy to drive over roads and over soft sand on a beach.

In water, the wheels are raised to be in line with the body, giving the Python a smooth planing hull like a speedboat.

Tourist DUKWs are a bright sight in Liverpool, UK.

SMALLEST PERSON-CARRYING VEHICLE

SOLOWHEEL

You can't get much smaller than a single wheel! The Solowheel is just that - one wheel with pedals to stand on and a small electric motor to drive it along.

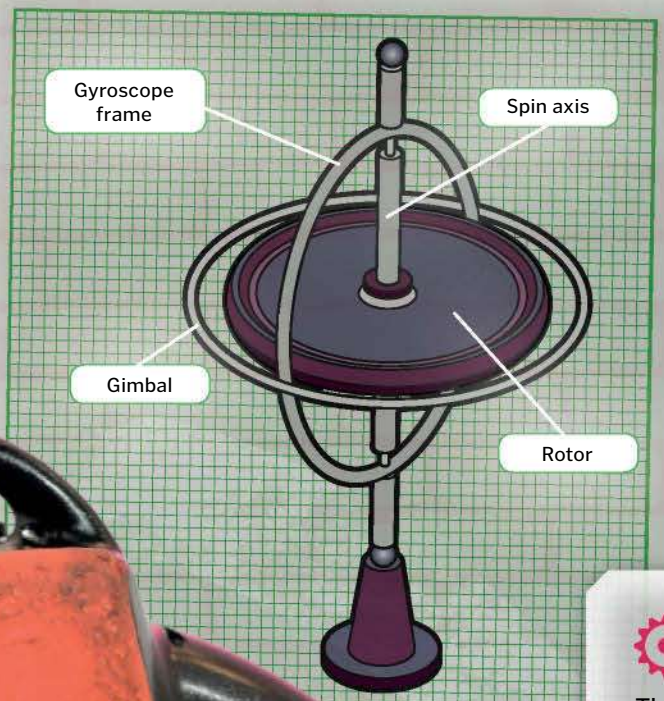
The rechargeable battery gives a range of 16 km and a top speed of 16 km/h. To control acceleration, the rider leans forwards (to go faster) or backwards (to slow down or stop). Leaning to right or left controls the direction of travel. The Solowheel works as a gyroscope and is self-balancing once the wheel is spinning.

The rider controls direction and speed by leaning right, left, forwards or backwards.

SOLOWHEEL	
WEIGHT	11 KG (MAX LOAD 99 KG)
TOP SPEED	16 KM/H
SIZE	48 CM TALL; 20 CM THICK (PEDALS FOLDED)
COST	$1,795
POWER	1 KW

SEGWAY

The Segway PT (Personal Transporter) has two wheels, a platform to stand on and a handle to hold. It's much chunkier and less portable than the Solowheel, but can go further and tackle rougher terrain. The Segway has five sensors and two accelerometers to sense its angle with respect to gravity 100 times per second. It then applies motor torque to the wheels to rebalance, turn, accelerate or slow down as necessary.



GYRO-POWER

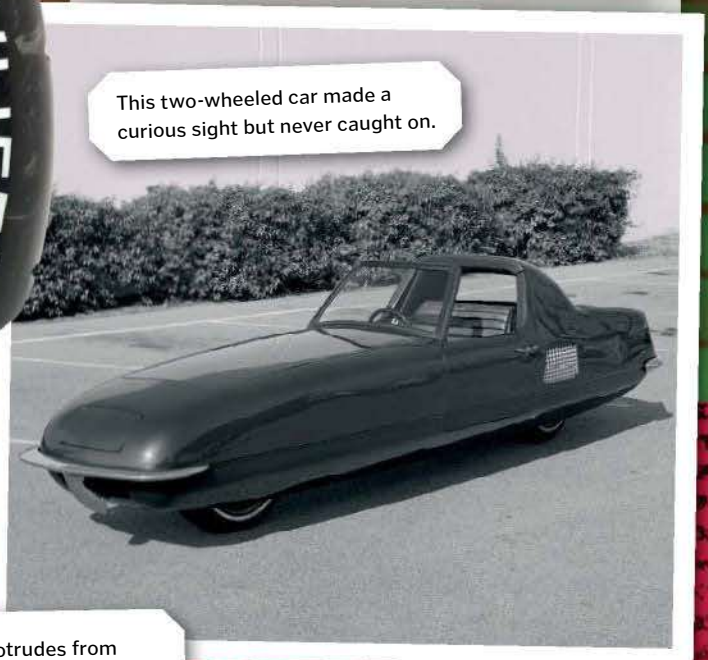
All self-balancing vehicles have a gyroscope at their heart. This comprises a spinning disc held inside a ring. If the disc is tilted as it spins (rotating the spin axis), the gyroscope adjusts by trying to tilt in the opposite direction to the force applied, so correcting its position. Three gyroscopes provide the autopilot system in a plane.

GYRO CAR

The Gyro-X was a prototype self-balancing car developed in California in 1967. With only two wheels and a gyroscope to maintain balance, the Gyro-X was the first – and last – of its kind, as the manufacturer went out of business before launching it. Despite its odd looks, the car could reach 200 km/h. While waiting three minutes for the 50-cm gyroscope to get up to speed, small outrigger wheels kept the car upright.

A fold-down pedal each side of the wheel is all the rider has to balance on.

The wheel protrudes from the casing only at the very bottom, so clothing can't get caught in the wheel.



This two-wheeled car made a curious sight but never caught on.

FURTHEST HUMAN-POWERED FLIGHT

MIT DAEDALUS 88

The MIT Daedalus 88 flew a record-breaking 115 km, powered by Olympic cyclist Kanellos Kanellopoulos. It took three hours, 54 minutes, 59 seconds - also setting the record for the longest human-powered flight.

The cyclist has to keep cycling all the time to keep the plane flying. The power from the pedals turns a drive shaft and goes through two gear boxes to turn the polystyrene propellor. Before take-off, the fragile wings must be supported by assistants running alongside the craft.

THE FIRST DAEDALUS

The flight was inspired by the mythical flight of Daedalus in ancient Greek myth. Daedalus and his son, Icarus, were imprisoned in Crete. Daedalus built them both sets of wings made from feathers, string and wax with which to escape. Icarus flew too high. The sun melted the wax and he fell to the sea and drowned, but Daedalus's flight was successful.

The frame and guide wires are made of Kevlar – a very tough and light material.

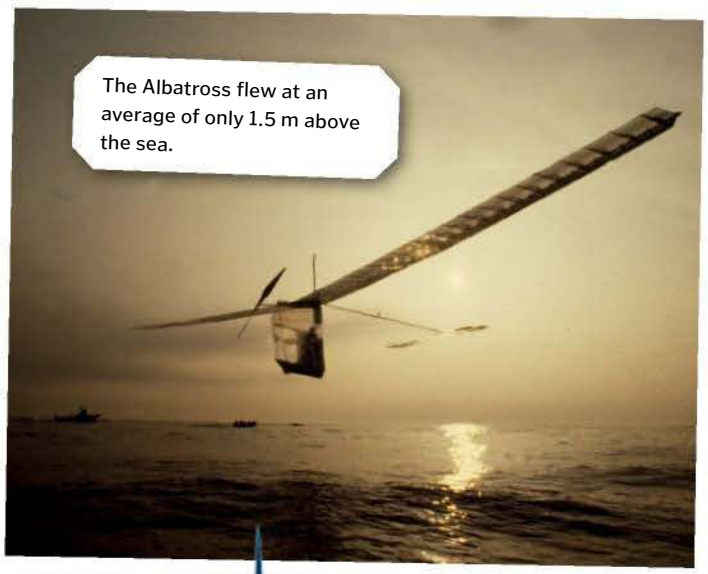
In myth, Daedalus was the first to try human-powered flight.

MIT DAEDALUS 88

WHEN	1998
HOW HEAVY	31 KG
SIZE	8.6 M LONG; 34 M WINGSPAN

CROSSING THE CHANNEL

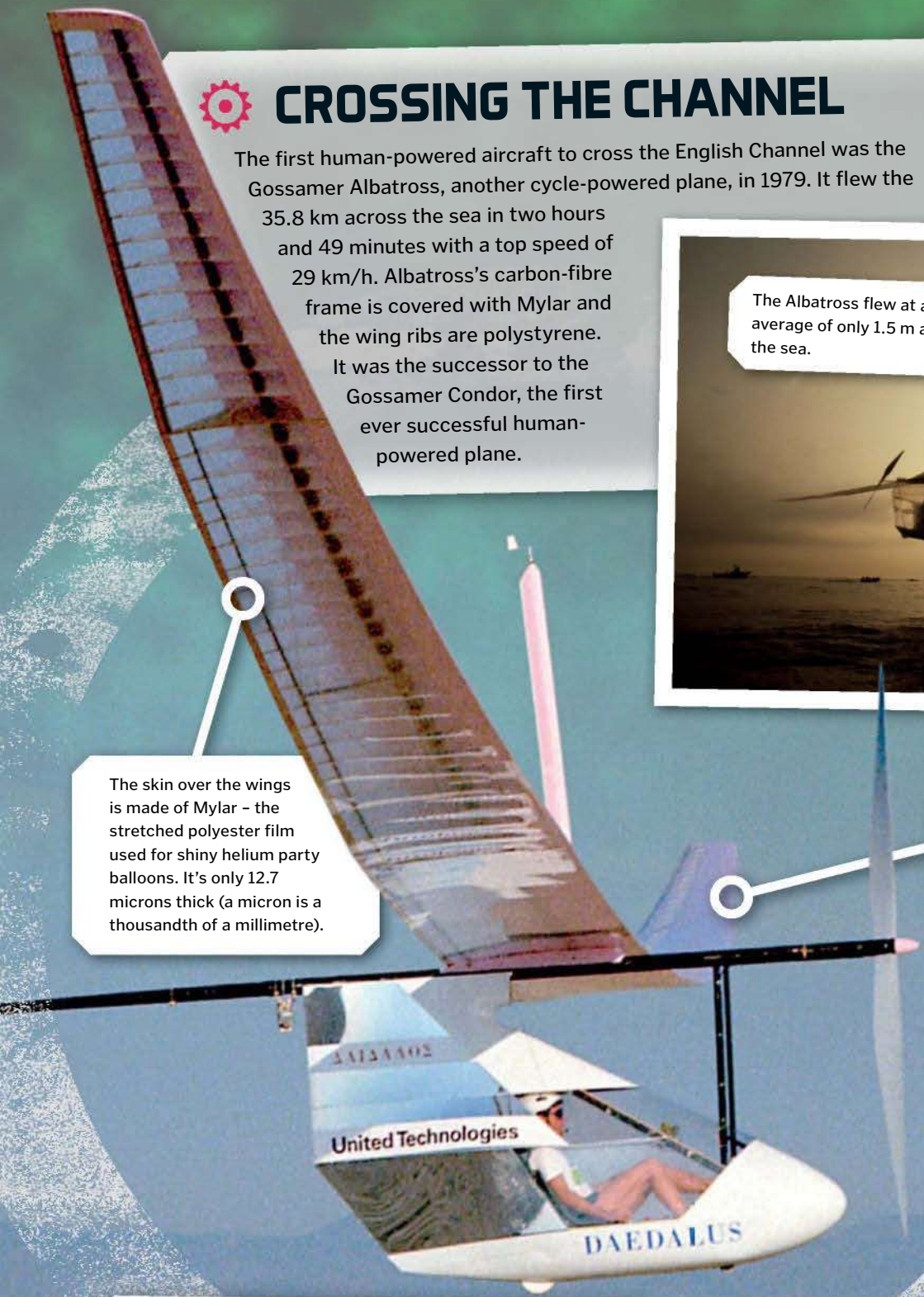
The first human-powered aircraft to cross the English Channel was the Gossamer Albatross, another cycle-powered plane, in 1979. It flew the 35.8 km across the sea in two hours and 49 minutes with a top speed of 29 km/h. Albatross's carbon-fibre frame is covered with Mylar and the wing ribs are polystyrene. It was the successor to the Gossamer Condor, the first ever successful human-powered plane.



The Albatross flew at an average of only 1.5 m above the sea.

The skin over the wings is made of Mylar – the stretched polyester film used for shiny helium party balloons. It's only 12.7 microns thick (a micron is a thousandth of a millimetre).

At 32 m, the wingspan of the Daedalus is larger than that of most Boeing 737s.



FLAPPING WINGS

The first successful human-powered ornithopter is the Snowbird, though the first design for a flapping-wing plane was drawn up by Leonardo da Vinci in 1485! Snowbird has a wingspan of 32 m and is made mostly from carbon fibre, wood and foam.

FIRST FLYING HOVERCRAFT

19XRW HOVERWING

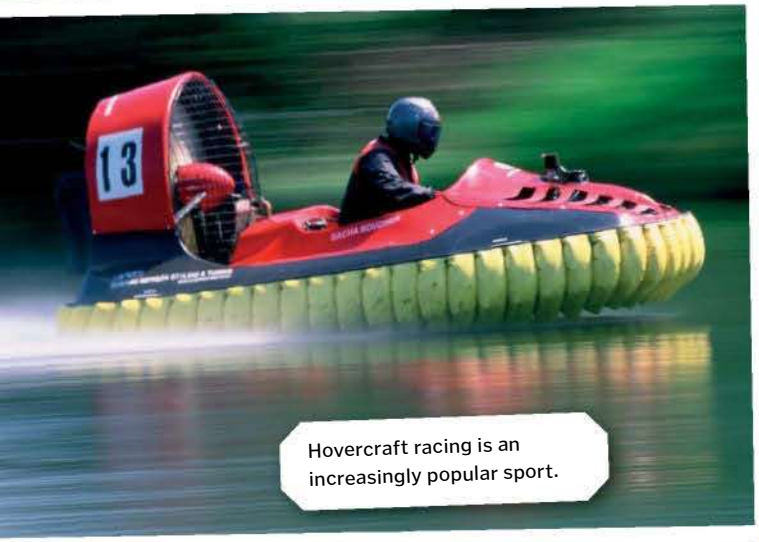
All hovercraft float on a cushion of air, but this hovercraft really flies! The 19XRW Hoverwing is a personal hovercraft with wings - a real cross between hovercraft and plane.

It can hover 28 cm above land or water on its vinyl-coated Nylon hover skirt - but with the wings fitted it can rise to 6 m and fly over rough terrain or choppy seas. It can also 'jump' up to 7 m to clear obstacles! With its twin-cylinder, turbocharged engine it can reach 126 km/h and travel for 225 km or four hours before refuelling.

Removable wings convert the Hoverwing between a sleek hovercraft and a plane. The wings roll up to fit inside the Hoverwing while not in use.

FAST AND FLIGHTY

Formula 1 racing hovercraft are small, light personal hovercraft driven by a pilot on a track that is part land and part water. There are no restrictions on size or power in these races.



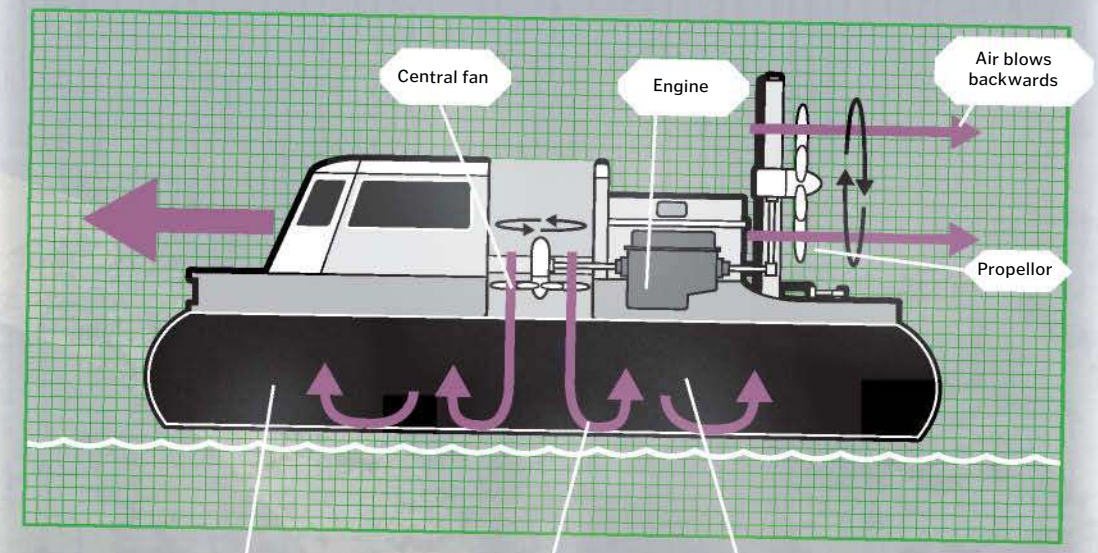
Hovercraft racing is an increasingly popular sport.

19XRW HOVERWING

WEIGHT	520 KG
TOP SPEED	126 KM/H
SIZE	5.8 M LONG; 2.3 M WIDE; 2 M TALL
COST	£150,000
POWER	176 KW

HOW A HOVERCRAFT WORKS

To move, the hovercraft has to lift off the ground and go forwards at the same time. An engine drives two fans. One of these inflates the skirt, making a cushion of air between the craft and the ground or water and lifting it. The other pushes air out of the back, providing thrust that drives the hovercraft forwards.



A 1.5 m thrust propellor drives the hovercraft forwards, while an 86-cm, four-blade lift fan keeps it airborne (or skirt-borne).

The super-strong hull is made of Kevlar and carbon fibre over a lightweight foam core that provides positive floatation, making the Hoverwing unsinkable.

FASTEST HOVERER

The fastest hovercraft ever was specially streamlined Universal UH19P hovercraft called Jenny II. With Bob Windt as pilot, Jenny II reached 137.4 km/h in the 1995 World Hovercraft Championships in Portugal. It had a V6 engine driving two fans, one at the rear propelling the hovercraft forwards, and one underneath, providing lift.

SMALLEST JET FLIER

JETWING

The idea of a personal jet pack is very exciting - it's been in comics and movies for years. The JetWing personal flier is getting close. With a wingspan of just 2.4 m it's the smallest jet flier in the world.

The wing was designed by the Swiss pilot Yves Rossy. He has to launch himself from a helicopter or hot-air balloon and land by parachute. The only controls are a grip throttle to control speed and an altimeter that speaks the altitude. Rossy crossed the Grand Canyon and the English Channel using JetWing.

The wing and its jet engines fix onto the pilot's back with straps around the shoulders, chest, waist and thighs. The pilot steers by moving his head and body to shift his weight.

JUST LIKE FLASH GORDON

NASA developed the Manned Maneuvering Unit jet pack in the 1980s for use by astronauts outside a spacecraft. A real jet pack, like a superhero uses, is still some way off. In space, only a little thrust is needed to move a human, but on Earth a great deal of power would be needed from the jet pack.

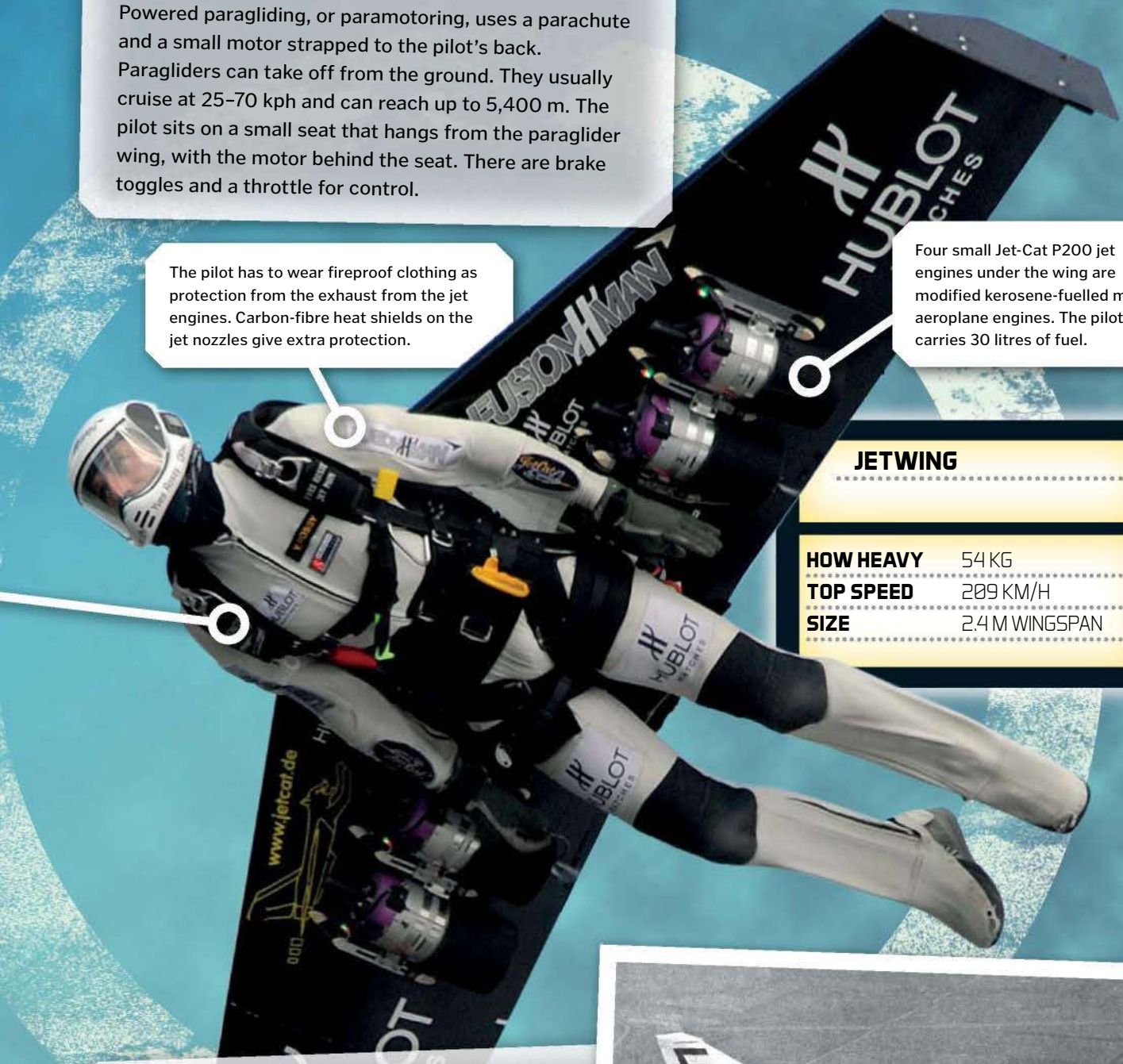
The force from the jet pack is clearly visible over water.

POWERED PARACHUTES

Powered paragliding, or paramotoring, uses a parachute and a small motor strapped to the pilot's back. Paragliders can take off from the ground. They usually cruise at 25–70 kph and can reach up to 5,400 m. The pilot sits on a small seat that hangs from the paraglider wing, with the motor behind the seat. There are brake toggles and a throttle for control.

The pilot has to wear fireproof clothing as protection from the exhaust from the jet engines. Carbon-fibre heat shields on the jet nozzles give extra protection.

Four small Jet-Cat P200 jet engines under the wing are modified kerosene-fuelled model-aeroplane engines. The pilot carries 30 litres of fuel.



JETWING

HOW HEAVY	54 KG
TOP SPEED	209 KM/H
SIZE	2.4 M WINGSPAN

TINY PLANE

The Bede BD-5 was an ultralight real aircraft sold in kit form in the 1970s. With a single seat and wingspan of 4.26–6.55 m, there were several versions including a jet-powered one, the BD-5J, which could reach 480 km/h. A Bede BD-5J featured in the James Bond film Octopussy.

SNEAKIEST SPYPLANE

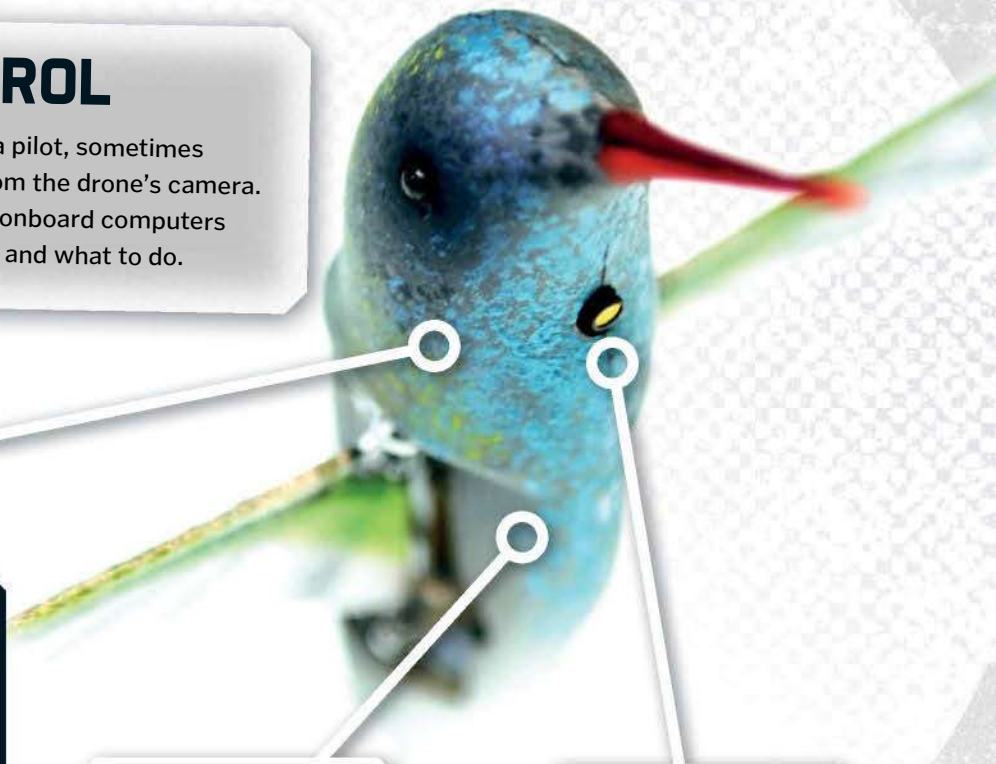
NANO HUMMINGBIRD

Is it a bird? Is it a plane? It's both! The Nano Hummingbird is actually a drone - an unmanned aerial vehicle (UAV) used for surveillance. But it's cunningly disguised as a hummingbird to help it go unnoticed.

The Nano moves just like a real hummingbird: it flaps its wings and can hover, even in a gust of wind. It climbs and descends vertically, can fly forwards, backwards and sideways (left and right), and rotate clockwise and anti-clockwise. It can even fly through a doorway and send video from inside a building.

SELF-CONTROL

The Nano is controlled remotely by a pilot, sometimes working only from the video feed from the drone's camera. Other drones are autonomous, with onboard computers making decisions about where to go and what to do.



The body can be coloured to match real hummingbirds local to the area where the Nano is being used.

NANO HUMMINGBIRD

WHEN	2011
HOW HEAVY	19 G (0.019 KG)
TOP SPEED	18 KM/H
SIZE	16 CM WINGSPAN

It's the same size and shape as a real hummingbird – larger than most species, but smaller than the largest real hummingbirds.

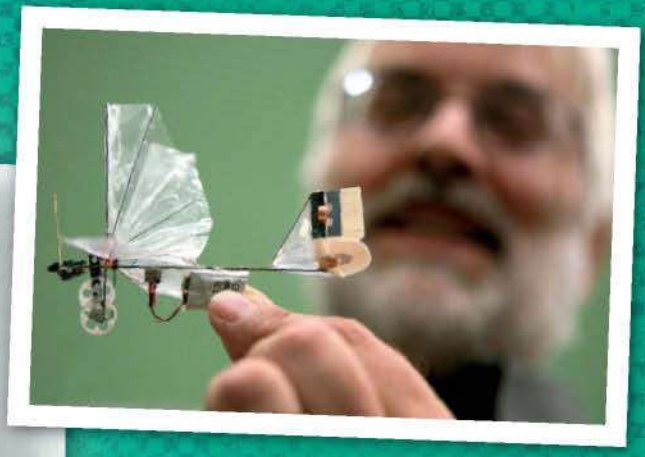
A tiny camera is hidden in the underside of the Nano and sends a live video feed to the remote pilot.

WHO'S LOOKING?

Military drones spy on enemies, but there are lots of other uses. In some countries, police use drones to monitor traffic, watch borders and look out for smugglers and pirates.

Drones are used for security over large areas (such as farms), and for checking the safety of oil pipelines that run over deserts.

They can even be used in search-and-rescue missions, searching for people lost at sea or in mountains.



DRONING ON

Some drones use different types of sensors, not just cameras. They can be used to detect levels of chemicals to monitor pollution, to check windspeeds around hurricanes, to search for underground oil or mineral deposits and even to track the movements of tagged animals.

The BBC penguin-cam slides over ice to sneak up on birds!

SMALLEST SUB

PERSONAL SUBMARINE

How would you like your own personal submarine? Several people have built their own. This one was made by Mikhail Puchkov in Ryazan, Russia. He built it secretly in his attic and tried it out in the middle of the night when no one could see.

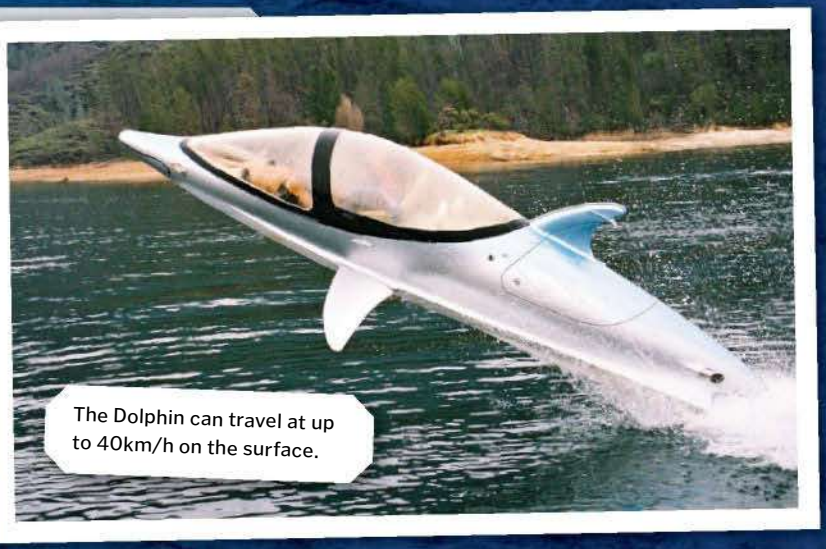
Puchkov's submarine can travel at 7.4 km/h and can go from St Petersburg to an island near Finland and back without stopping. The trip is a total of 320 km.

The body is made of fibreglass. There is just enough room inside for one person.

Originally only pedal-powered, the latest version of Puchkov's submarine has an engine for use on the surface and a different motor for underwater use.

PERSONAL DOLPHIN

People who don't want to build their own submarine can buy a personal submersible. One of the coolest must be the Dolphin Seabreacher – styled to look just like a dolphin! It can leap and even roll like a dolphin, and dive to 5 m for short periods. Each one is custom built – it can be very dolphin-like or disguised as a shark or whale.



The Dolphin can travel at up to 40km/h on the surface.

Tiny portholes allow the pilot to see out.

UNDERWATER CYCLING

The Omer-8 submarine is the latest in a line of person-powered submarines created by a student team in Montreal, Canada. The pilot cycles to drive the propellor which pushes the sub through the water. The propellor has a sophisticated electronic control system, though – it's more advanced than Puchkov's sub and can go at twice the speed.

DOWN WITH THE FISHES

Small submersibles are used by scientists and even tourists to watch fish in their natural environment. The Nemo 100 is a German mini-submarine that takes tourists on dives to see the underwater wildlife of the Baltic Sea.

PERSONAL SUBMARINE

WHEN	1988 (FIRST SUCCESSFUL DIVE)
TOP SPEED	7.4 KM/H
SIZE	14.8 M (MODEL WITH ENGINE); 3 M (MODEL WITHOUT ENGINE)

DEEPEST DIVER

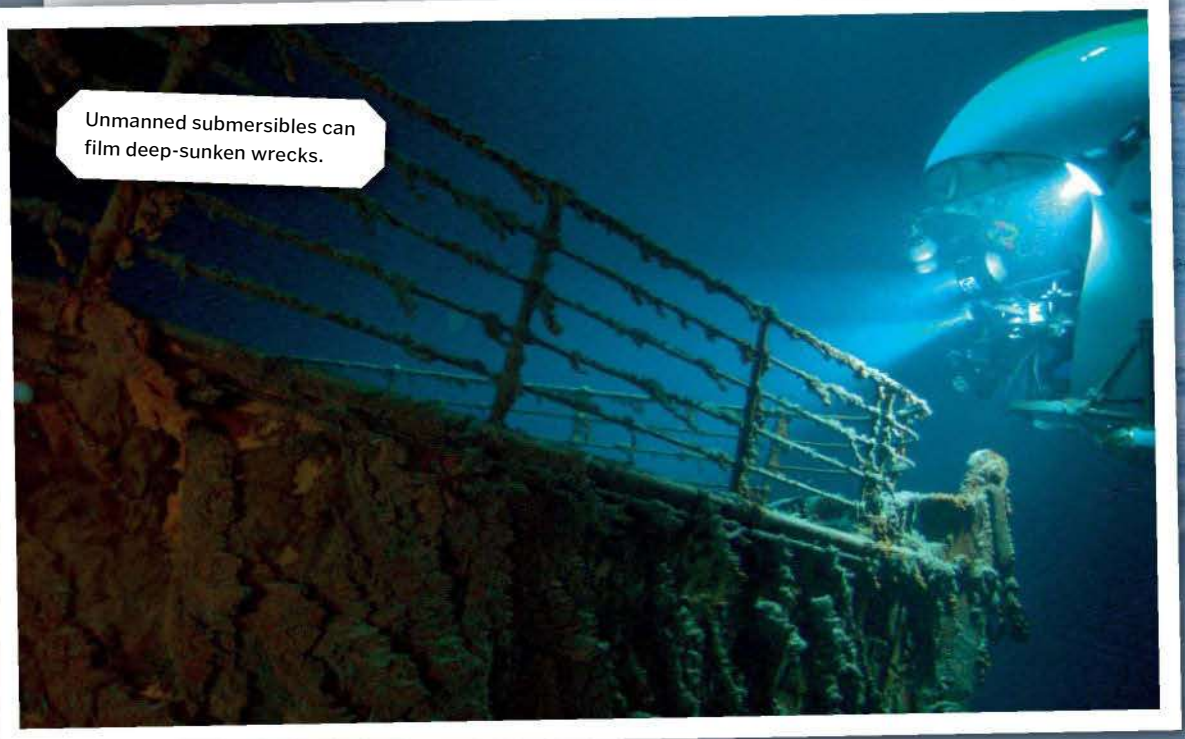
KAIKO

The deep sea is very, very deep. But the Kaiko unmanned submersible has been there - 10,911 m down in the Challenger Deep, the deepest area of sea on Earth.

Kaiko had sonar scanners and four video cameras to film and map the ocean floor. The submersible was lost when the cable connecting it to its launcher broke during a typhoon in 2003.

WHAT'S DOWN THERE?

Unmanned submersibles are used for lots of purposes. Some carry scanners, cameras and radar to help map and investigate the ocean floor. Others collect samples of water, rock and wildlife from areas like deep sea trenches, which have some of the harshest environments on Earth. Automated submersibles also used to take fascinating films in the deep sea.



Unmanned submersibles can film deep-sunken wrecks.

KAIKO

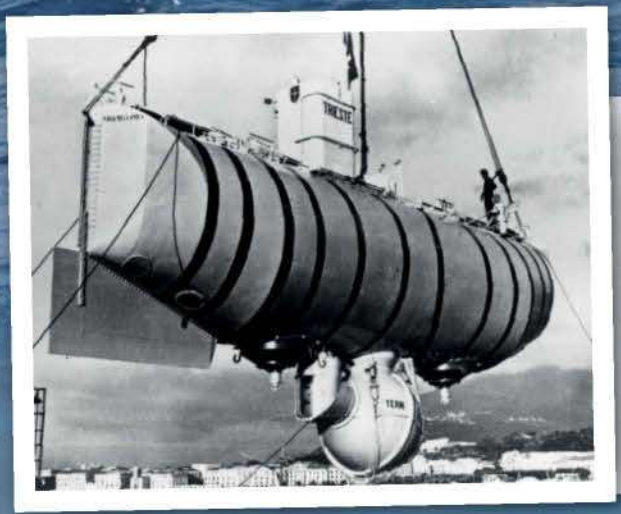
WHEN	1995
HOW HEAVY	5,000 KG
SIZE	3 M LONG

Kaiko was connected by 250 m of cable to a launcher which itself had 12 km of towing, power and communication cables linking it to a support ship at the sea's surface.

SUN POWER – UNDERWATER!

SAUV II is a solar-powered, unmanned submersible that can dive to 500 m. It has a 1 m2 solar panel that charges a lithium ion battery. It's used for monitoring sea conditions, coastal surveillance and security, and even for tracking water quality in reservoirs. It's remotely controlled by computer, and sends back data using a wireless connection.

Mechanical manipulating arms worked to collect samples from the sea bed. The arms could handle a raw egg without breaking it.



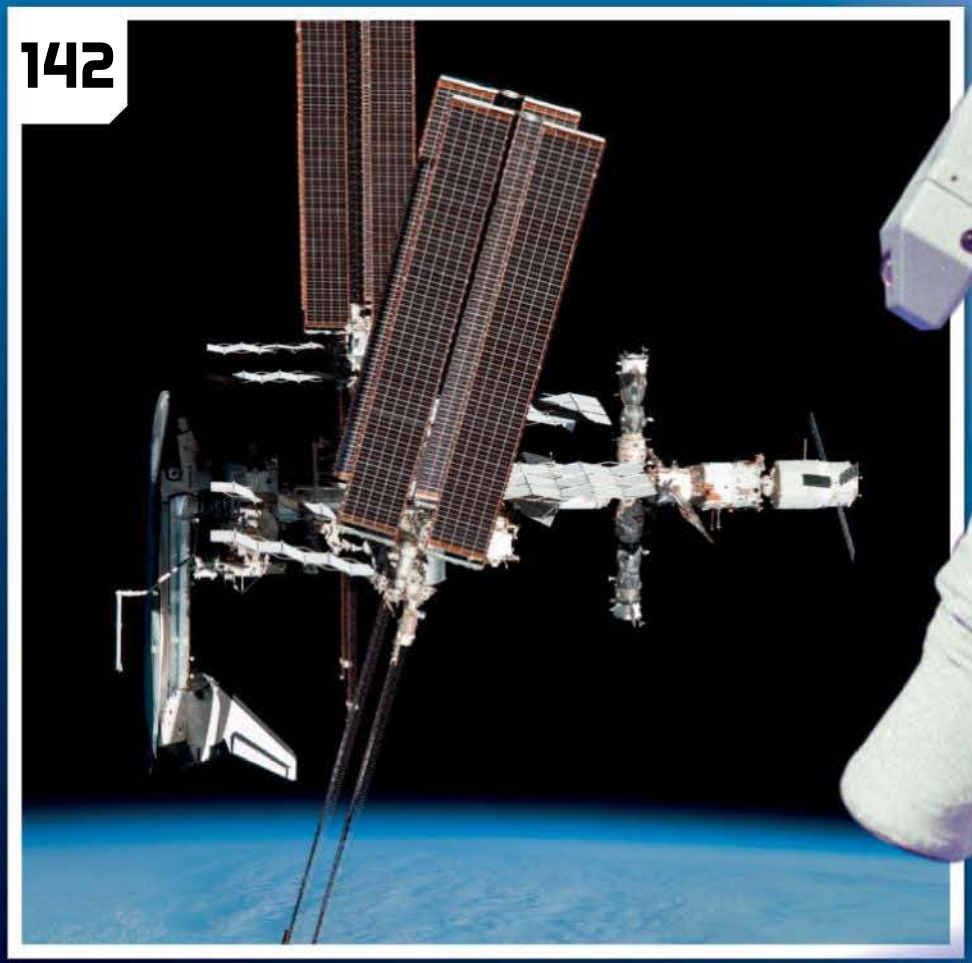
DEEPEST MANNED DIVE

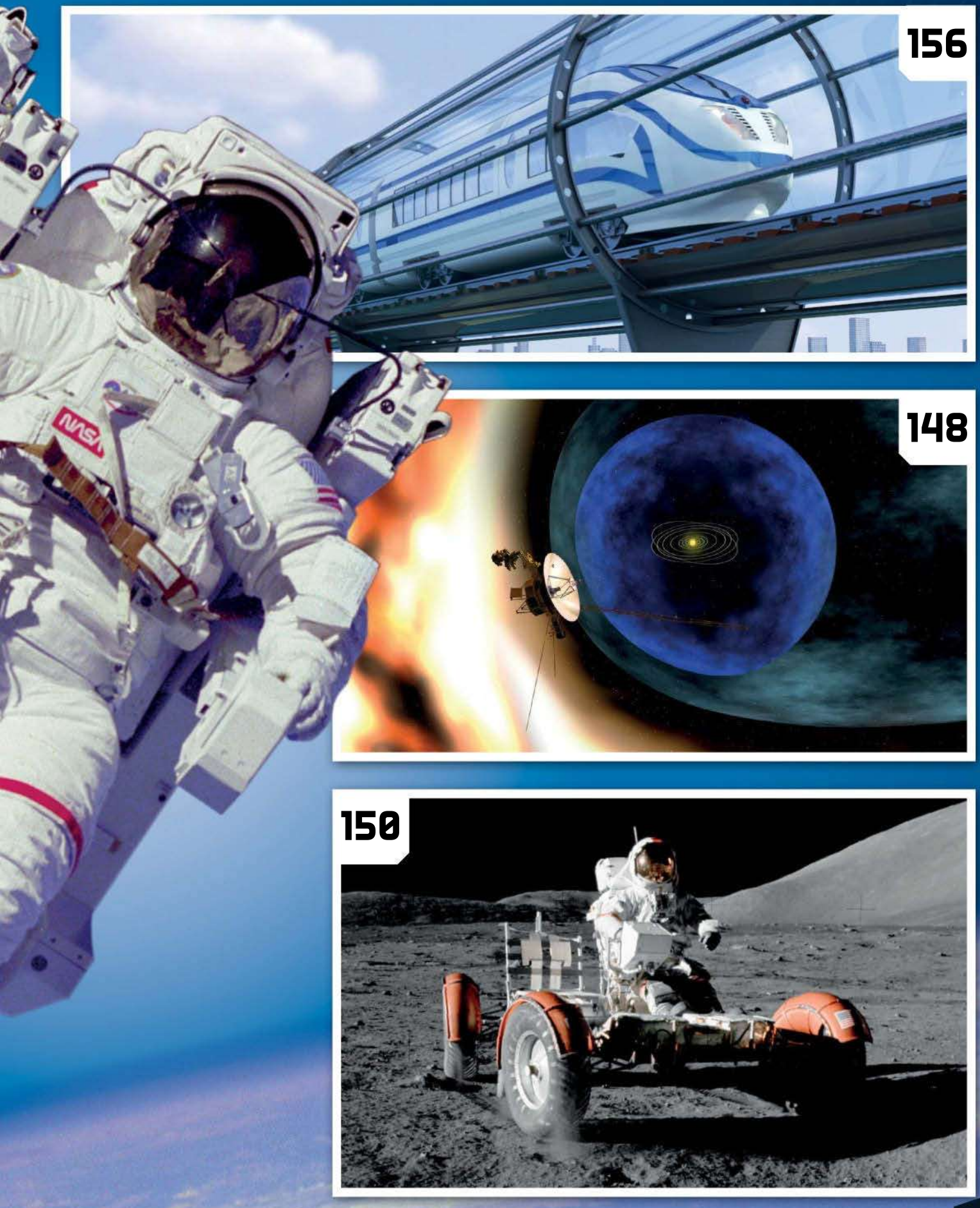
The deepest dive by a manned submersible was 10,911 m in the Challenger Deep trench in 1960 by the Trieste. Beaneath a 15 m long float chamber, it had a spherical cabin for a crew of two, with metal walls 12.7 cm thick to withstand 1,000 times atmospheric pressure. It took three hours and 15 minutes to descend to the ocean floor.

HOW IT WORKS

AMAZING SPACECRAFT

HOW IT WORKS BOOK OF MEGA MACHINES

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MOST POWERFUL ROCKET

SATURN V

The Saturn V rockets were the most powerful ever created. The first Saturn V launched Apollo 4 in 1967 and the last was used in 1973 to launch the Skylab space station.

The five rocket engines of the first stage started up 8.9 seconds before launch, firing 300 milliseconds apart. The engines burned 2,100,000 kg of rocket fuel in less than three minutes. If it had exploded on take-off, Saturn V would have generated as much energy as a small nuclear bomb.

SATURN V	
WHEN	1967
HOW HEAVY	2,800,000 KG (WITH FUEL) + PAYLOAD OF UP TO 120,000 KG
TOP SPEED	40,320 KM/H
SIZE	111 M LONG
POWER	34,500,000 NEWTONS OF THRUST

The five nozzles carry scorching-hot waste gases from the combustion chamber, blasting the rocket into space.

HOW SPACE ROCKETS WORK

In a rocket engine, the waste gases from burning fuel push the craft forward. On Earth, the fuel is mixed with air, but in space there is no air so the rocket has to carry oxygen. The fuel is converted to a gas and mixed with oxygen in the combustion chamber.

STAGED LAUNCH

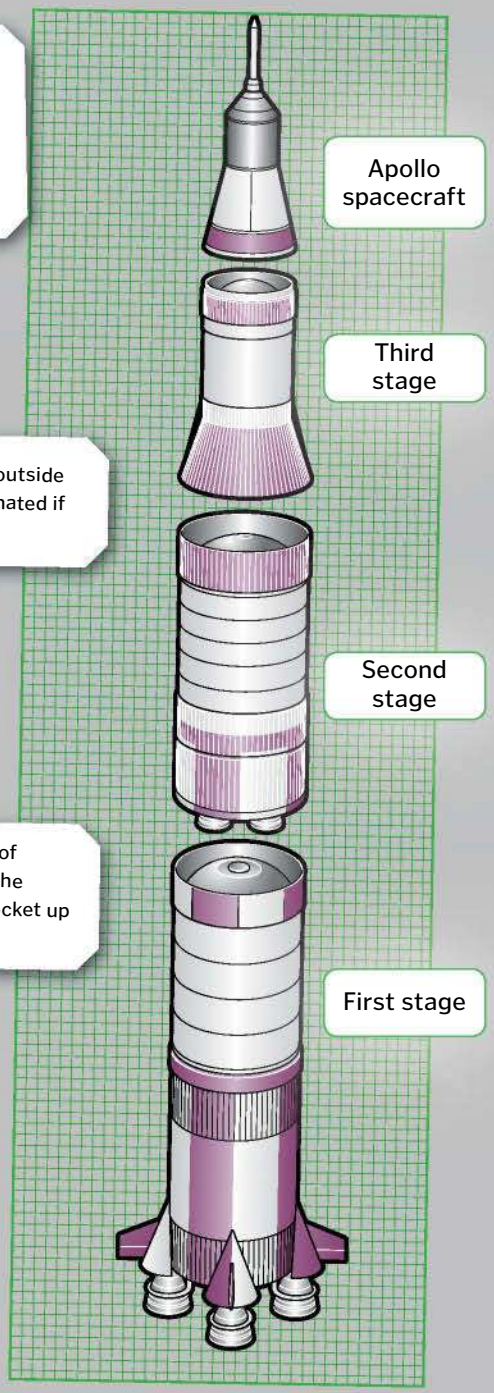
As each stage burned its fuel, it separated from the rocket and the next stage fired. The first two stages fell away into the ocean; the last either hit the Moon or stayed in space. After establishing orbit, the stage 3 rockets fired again to push the craft towards the Moon, reaching a speed of 40,320 km/h. That's more than 11 km per second!

	Time burning	Speed	To altitude
Stage 1	2 minutes, 41 seconds	9,920 km/h	109 km
Stage 2	6 minutes	25,182 km/h	175 km
Stage 3	2 minutes, 30 seconds	28,054 km/h	191 km

The rocket had three stages, each with its own fuel supply – rocket fuel for the first stage, and liquid hydrogen for the other two.

Explosives fixed to the outside could be remotely detonated if anything went wrong.

The immense power of gases blasting from the engines forced the rocket up into the air.



BIGGEST SPACECRAFT

THE INTERNATIONAL SPACE STATION

The largest human-made object in space is the International Space Station (ISS), started in 1998 and built up in a modular way from components carried by Space Shuttles and put together in space.

It's the ninth inhabited space station and the largest at 72 m long and weighing 450,000 kg. It's large enough to be seen with the naked eye from Earth. It has been permanently inhabited since November 2000. ISS is funded until 2020 and could stay in use until 2028.

The ISS is in orbit between 330 km and 410 km above Earth and completes 15.7 orbits each day.

Arrays of photovoltaic cells collect solar power for the ISS to use.

WORKING IN SPACE

The ISS provides laboratory facilities for carrying out experiments in microgravity and space conditions. These include work on astrobiology, astronomy, space medicine, physics, materials science and space weather. Space medicine studies the behaviour of the human body in space. It is essential to understand this before humans make long space flights or colonize other planets. Scientists also use a special detector to investigate mysterious dark matter. This could not be done anywhere else.

An astronaut conducts experiments aboard the ISS.

LIFE AWAY FROM HOME

Astronauts live on the ISS for months at a time. Sleep stations are scattered around the station. Crew wash with water jets and wipes, rather than showers. They eat packaged food, taking drinks and soup from bags with a straw. Knives and forks are held to metal trays with magnets to stop them floating away. Most food has sauce, to stop crumbs floating around.

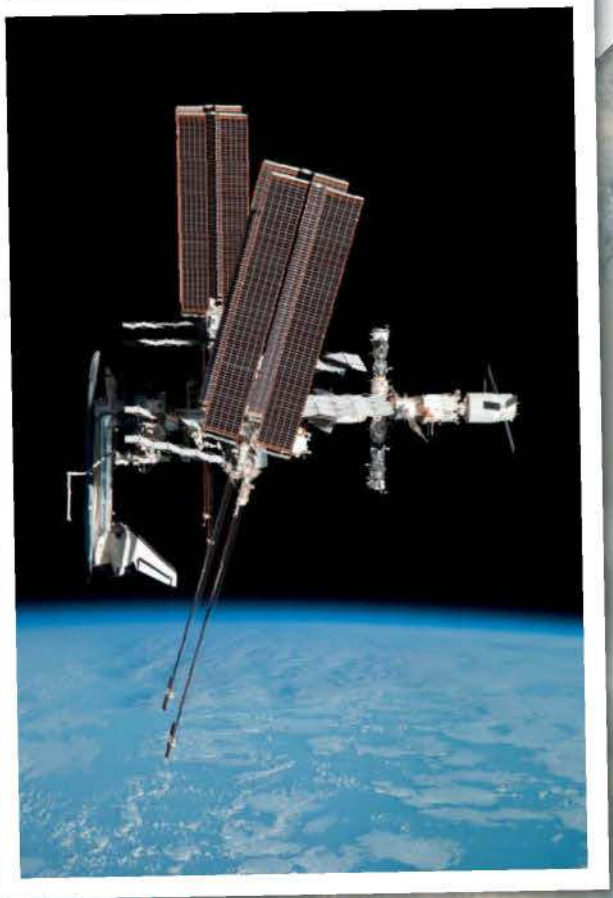
INTERNATIONAL SPACE STATION

WHEN	1998-PRESENT
WEIGHT	450,000 KG
TOP SPEED	27,743.8 KM/H
POWER	0.47 KW (AT LAUNCH)
SIZE	72.8 M LONG; 108.5 M WIDE; 20 M HIGH

The ISS is made up of a set of modules containing laboratories, command modules, crew quarters, stores and equipment.

GOING TO WORK

Astronauts and equipment are taken to the ISS by smaller spacecraft. Equipment and supplies are often ferried there in unmanned craft. Each craft has to dock with the ISS – a complex and precise manoeuvre. It involves the two vehicles colliding at an exact position, with giant springs absorbing the shock of the impact.



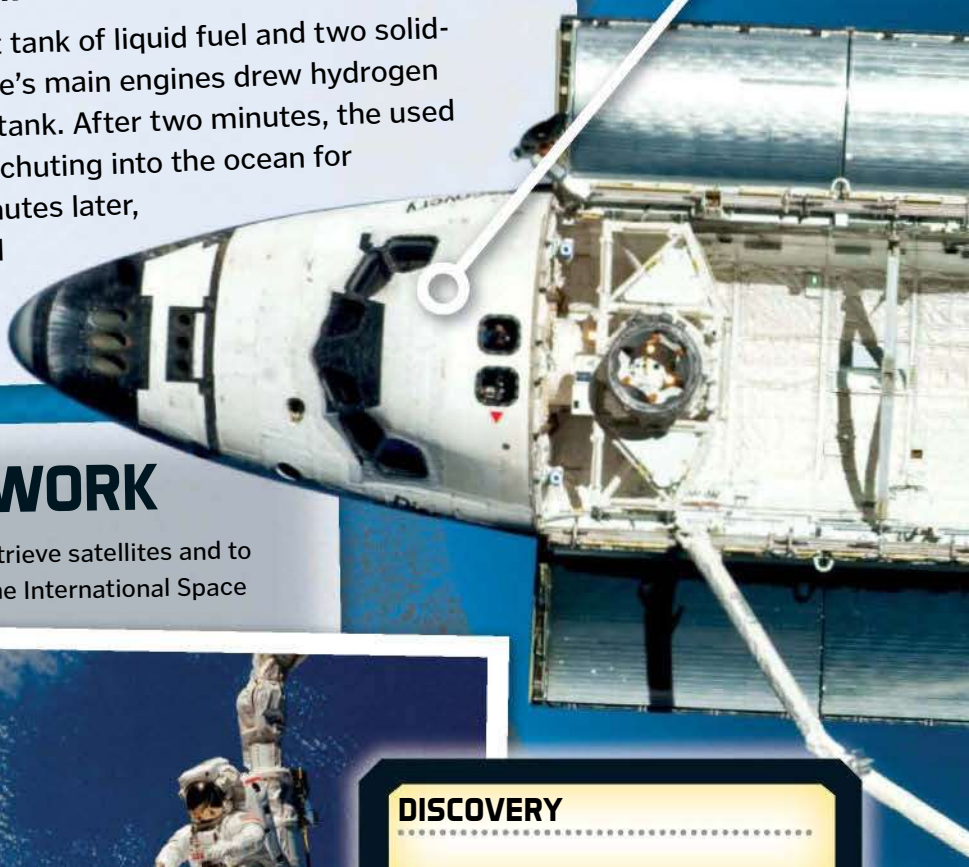
MOST HARDWORKING SPACECRAFT

DISCOVERY

The Space Shuttle Discovery completed 39 missions between 1984 and 2011. It travelled 238,539,663 km, orbiting the Earth 5,830 times. That makes it the hardest working of the five Space Shuttles.

Discovery launched with a giant tank of liquid fuel and two solid-fuel rocket boosters. The Shuttle's main engines drew hydrogen and oxygen from the main fuel tank. After two minutes, the used rocket boosters detached, parachuting into the ocean for recovery and re-use. Seven minutes later, the external fuel tank detached and burnt up in the atmosphere.

The crew compartment was home to the astronauts for up to two weeks. The flight deck was above, with the sleeping, storage and bathroom area beneath it.



SHUTTLE AT WORK

The Shuttles were used to deploy and retrieve satellites and to deliver astronauts and components to the International Space Station. A reaction control system (RCS) used 14 jets to nudge the Shuttle round to control its direction, using the same self-igniting fuel-mix as the OMS engines (see opposite). A remote manipulator arm that extended from the cargo section positioned and retrieved satellites.

DISCOVERY

WHEN	1984-2011
HOW HEAVY	2,050,000 KG
TOP SPEED	27,875 KM/H
SIZE	23.7 M WINGSPAN; 56 M LONG

TELESCOPE IN SPACE

In 1990, Discovery carried the Hubble Space Telescope into orbit. Just 4.3 m across, it is a visible-light telescope that collects and sends to Earth crystal-clear images of the stars. Because it is outside Earth's atmosphere, there is no distortion or background light to interfere with the images.

The Orion nebula, photographed by the Hubble Space Telescope, is about 1,350 light years away and 24 light years across.

Three main engines at the rear were each 4.3 m long, 2.3 m across the nozzle and 3,039 kg in weight. They burned mixed liquid hydrogen and oxygen.

Exhaust gases left the nozzles at 10,000 km/h. Each engine produced up to 2,090,664 N of thrust.

ENGINES IN ORBIT

Two orbital manoeuvring system (OMS) engines controlled the position of the Shuttle. Their rocket engines were powered by two gases which, mixed together, self-combusted with no spark necessary. Each engine could produce 26,000 N of force, could start and stop 1,000 times, and burn for a total of 15 hours.

To land, the Shuttle faced Earth and the engines fired it for the descent.

FASTEST HUMAN TRIP

APOLLO 10

Three people have travelled at the fastest speed ever achieved by a human - the crew of Apollo 10, which reached 39,896 km/h in 1969.

Apollo 10 was the last of the practice flights for the Moon landing. It went into low orbit around the Moon, then the lunar module detached and descended to 14 km above the Moon's surface, but did not land. It travelled a total distance of 1,334,850.26 km in eight days, 23 minutes and 23 seconds.

The Apollo 10 crew (left to right): Eugene Cernan, Thomas P. Stafford, John W. Young.

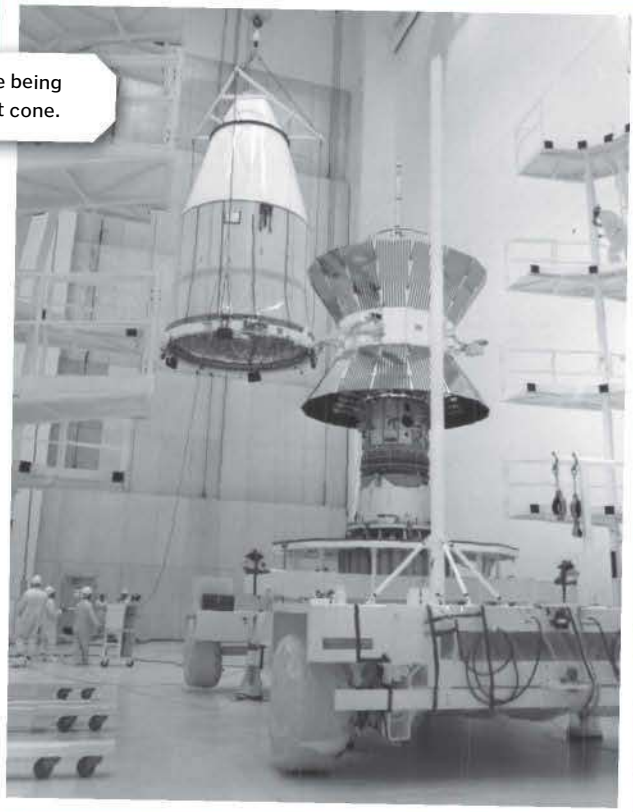
The lunar module is on top of the three-stage Saturn V rocket. The whole rocket is 110 m tall.

APOLLO 10

WHEN	1969
TOP SPEED	39,896 KHM/H
SIZE	110 M
POWER	33,350,000 NEWTONS OF THRUST
ENGINE	5 X F-1 ROCKET ENGINES

The launch escape system at the very top could blast the command module away from the rest of the rocket and parachute to safety if anything went wrong.

A Helios prototype being fitted into a rocket cone.



FASTEST FLIGHT

Although Apollo 10 was fast, the unmanned probe Helios 2 was even faster still, reaching a top speed of 252,792 km/h – 70.22 km/second - in April 1976.

Helios 1 and Helios 2 were launched in 1974 and 1976 to travel close to the Sun and collect data about cosmic rays, cosmic dust, solar plasma and solar winds. Helios 2 flew to within 0.29 AU of the Sun (about 43,500,000 km). The probes are still orbiting the Sun, but they no longer send data to Earth.

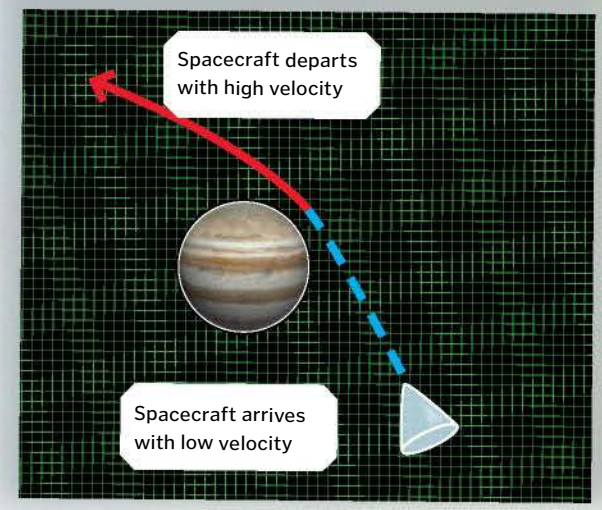
HOW TO GO REALLY FAST

Rockets work in the same way as jet engines – by producing thrust in the form of a burst of exhaust gas from the rear of a vehicle. In space, there is little gravity and no air resistance, so the same amount of thrust produces greater acceleration in space than on Earth.

Five F-1 rocket engines each 5.5 m long and capable of producing 6,670,000 N of thrust fire together to blast the rocket carrying Apollo 10 into space.

HOW TO CHEAT AND GO EVEN FASTER

Some spacecraft harness the gravitational field of a planet and use it as a sort of slingshot. This is called a gravity assist manoeuvre. The craft is pulled towards the planet by gravity, accelerating rapidly, then whizzes past, using the extra speed to accelerate into space.



FURTHEST TRAVELLING SPACE PROBE

VOYAGER 1

The most distant man-made object is the Voyager 1 probe, launched in 1977. It has travelled 18 billion km - it's at the edge of the Solar System and still going.

Voyagers 1 and 2 were launched to take advantage of an alignment of the planets that happens only once every 177 years and would enable Voyager 2 to visit Jupiter, Saturn, Uranus and Neptune in sequence.

Radioisotope thermoelectric generators produce electricity to run the instruments onboard Voyager, receive transmissions from Earth and send data back to Earth.

IS THERE ANYBODY OUT THERE?

Both Voyagers carry a gold disk and an instrument to play the disk, which holds 115 images of Earth, recordings of music from different times and places, and greetings spoken in 55 languages including Akkadian – last spoken 6,000 years ago. There is a diagram showing the location of our Sun and instructions on playing the disk which any advanced civilization could decode. A spot of uranium-238, which has a half-life of 4.51 billion years, will help any aliens work out when Voyager was made.

The Voyager disks are made of gold because it does not corrode.

Antennae for detecting radio and plasma waves.

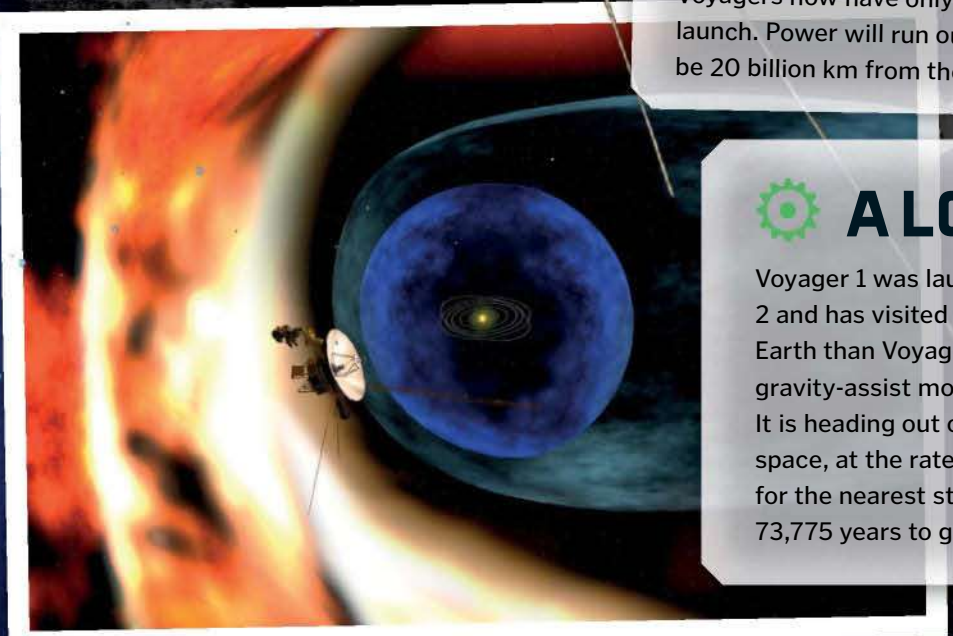
VOYAGER I

WHEN	1977-NOW
WEIGHT	773 KG
TOP SPEED	3.6 AU/YEAR; 61,600 KM/H
POWER	0.47 KW (AT LAUNCH)
ENGINE	3 X RADIOISOTOPE THERMOELECTRIC GENERATORS

Instruments for measuring and recording magnetic fields, solar wind and interstellar wind, detecting particles and cosmic rays and taking photographs.

POWERING THROUGH THE DARKNESS

The power for the Voyagers comes from the radioactive decay of plutonium-238, which has a half-life of 87.7 years. That and the deterioration of components means Voyagers now have only 57% of the power they had at launch. Power will run out in 2020, when Voyager 1 will be 20 billion km from the Sun. It will then drift.



A LONG PATH

Voyager 1 was launched slightly later than Voyager 2 and has visited fewer planets. It is further from Earth than Voyager 2 and travelling faster. It used a gravity-assist move from Saturn to boost its speed. It is heading out of the Solar System, into interstellar space, at the rate of 61,350 km/h. If it were heading for the nearest star (which it isn't), it would take 73,775 years to get there.

MOST INTREPID MOON ROVER

LUNAKHOD

The Lunakhod Moon Rover was the first autonomous land vehicle to be used outside Earth. It was put on the Moon in 1970 by the Soviet space programme, taken there by Luna 17.

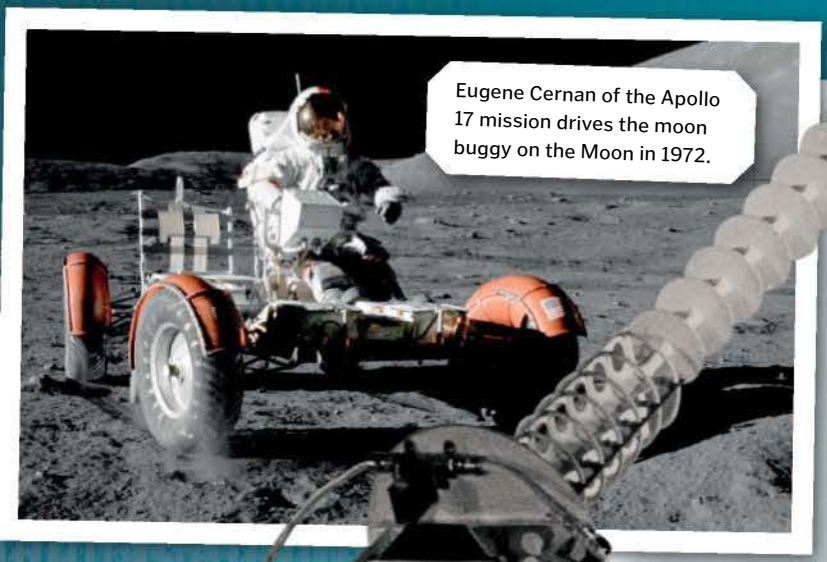
Lunakhod remained operational for 322 Earth days, making it the longest-lasting lunar rover. In that time it travelled 10.54 km, sent over 20,000 TV images back to Earth and tested the surface at 500 locations. NASA has located Lunakhod's position to within 1 cm.

Power for the rover was collected by solar cells on the underside of the lid during the two-week lunar day.

The eight wheels were each independently powered by electrical engines in sealed pressurised containers.

LUNAKHOD

WHEN	1970
HOW HEAVY	840 KG
TOP SPEED	2 KM/H
SIZE	1.7 M LONG; 1.35 M HIGH



Eugene Cernan of the Apollo 17 mission drives the moon buggy on the Moon in 1972.

FIRST MANNED LUNAR ROVER

The Moon Buggy, or Lunar Roving Vehicle (LRV) developed by NASA was used on three Apollo Moon missions (15, 16 and 17). All three buggies are still on the Moon. Powered by a non-rechargeable 36-volt battery, the Moon Buggy had a range of 92 km. It had a frame of aluminium tubing, weighing a total of 210 kg on Earth (35 kg in the Moon's reduced gravity) and front- and rear-wheel drive to negotiate the difficult surface.

Antennae and four television cameras collected and transmitted film of the Moon's surface.

ROLLING, WALKING AND CLIMBING

NASA's Athlete robotic rover, which has not been used yet, has six wheels. It can roll over land like the Moon, or lock its wheels and 'walk' over very rough, sandy or steep ground. A new version in development will be able to climb vertical cliff-faces using a grappling hook. It can carry a payload of 300 kg (Earth mass) on its large, flat base.

MOST RESILIENT MARS ROVER

OPPORTUNITY

Two rovers sent to Mars in 2003 landed in 2004 and set about exploring the surface of the planet, sending images and other data back to Earth. Originally intended to work for 92 days, one of them - Opportunity - was still operational nine years later in 2013.

Opportunity and its twin Spirit landed on Mars coccooned inside balloons and airbags and with a parachute to slow their descent. They were dropped from the Delta II rocket used to carry them to Mars, a journey that took 202 days. Opportunity is powered by solar panels and a rechargeable lithium-ion battery.

WORKING HARD

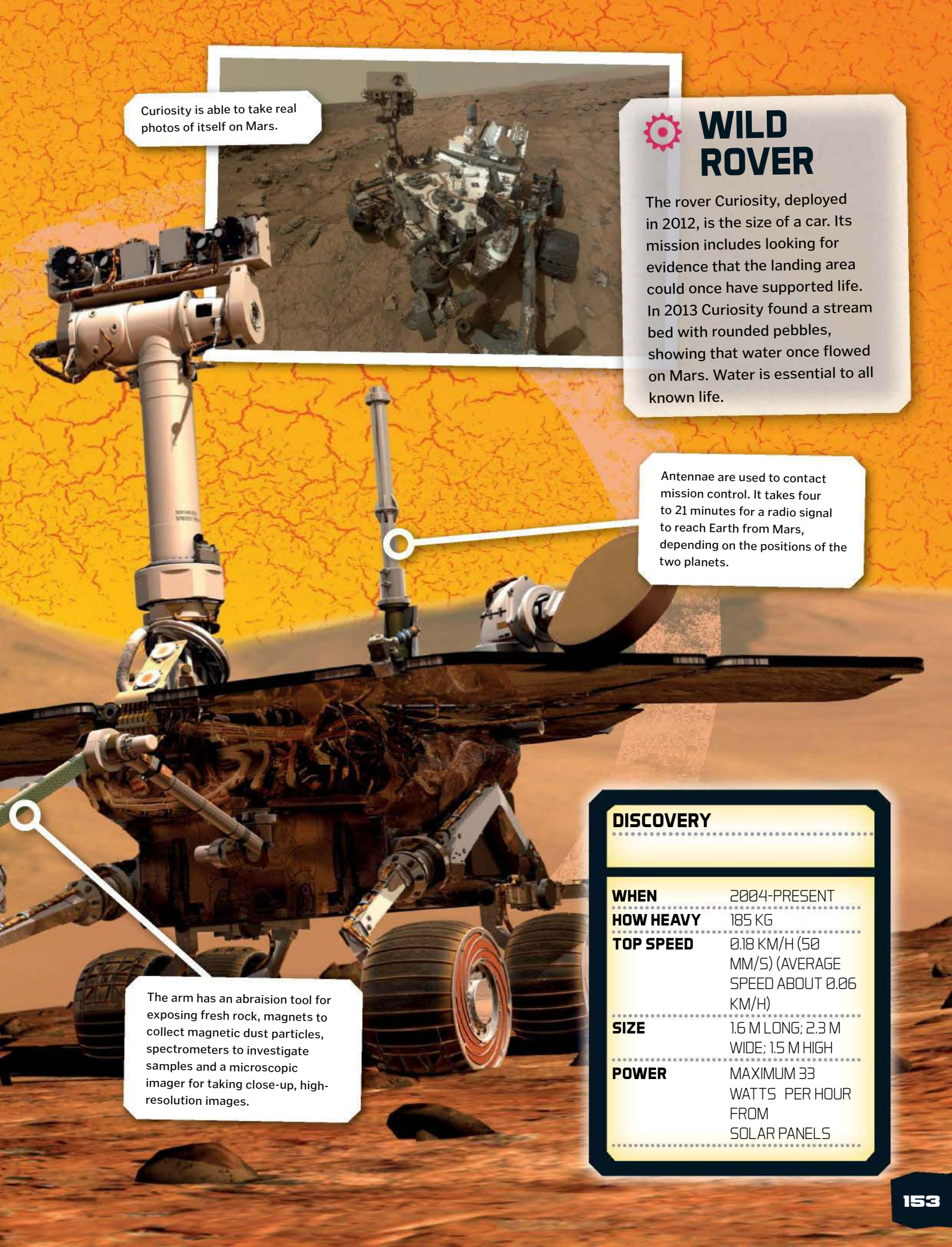
Opportunity has spent its time photographing the Martian landscape and collecting and examining samples of rock and soil. Its actions are controlled from Earth.

In 2006, the software controlling Opportunity was updated to enable it to make its own decisions about whether to photograph a scene and whether to collect a sample. This change cuts the amount of data sent between the rover and Earth.

Each wheel has its own motor. The rover has front and rear steering and can operate at an angle of 30°, so it can traverse slopes.

ROLL-OVER ROVER

A design for an unusual Mars rover is being investigated by NASA. The tumbleweed rovers would be blown around the planet by the Martian winds. One design has an internal network of sails; another looks like a giant balloon. The wind would carry the rovers to places too difficult to reach by other methods.



Curiosity is able to take real photos of itself on Mars.

WILD ROVER

The rover Curiosity, deployed in 2012, is the size of a car. Its mission includes looking for evidence that the landing area could once have supported life. In 2013 Curiosity found a stream bed with rounded pebbles, showing that water once flowed on Mars. Water is essential to all known life.

Antennae are used to contact mission control. It takes four to 21 minutes for a radio signal to reach Earth from Mars, depending on the positions of the two planets.

The arm has an abraision tool for exposing fresh rock, magnets to collect magnetic dust particles, spectrometers to investigate samples and a microscopic imager for taking close-up, high-resolution images.

DISCOVERY

WHEN	2004-PRESENT
HOW HEAVY	185 KG
TOP SPEED	0.18 KM/H (50 MM/S) (AVERAGE SPEED ABOUT 0.06 KM/H)
SIZE	1.6 M LONG; 2.3 M WIDE; 1.5 M HIGH
POWER	MAXIMUM 33 WATTS PER HOUR FROM SOLAR PANELS

FIRST SPACE-WALK PACK

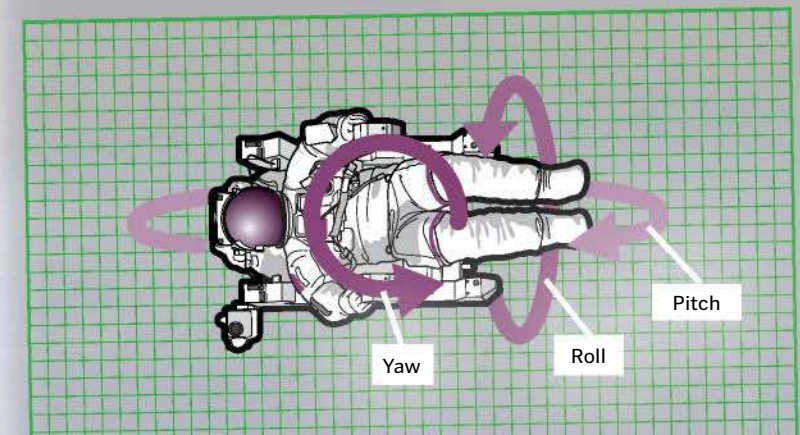
MANNED MANEUVERING UNIT

Astronauts don't just stay inside their spaceships all the time. For moving around in space - spacewalks - they can use jet-propelled packs called Manned Maneuvering Units (MMU). The MMU was used in spacewalks on three missions in 1984.

The MMU had no engine, but used bursts of nitrogen, stored as a liquid and quickly turning to gas, to produce thrust, pushing the astronaut through space. The nitrogen escaped through one or more of 24 nozzles pointing in different directions.

UP, DOWN, LEFT, RIGHT AND ROUND AND ROUND

The astronaut used the left-hand controller to produce acceleration going forwards, backwards, up, down, left and right. The right-hand controller produced rotational acceleration to control roll, pitch, and yaw – the way a vehicle (or astronaut) turns around axes in three directions. The controls could be locked when the settings were right, leaving the astronaut's hands free for work.



Twenty-four nozzles at different points around the pack produced thrust in different directions.

The unit fitted onto the astronaut's back, over the life-support system and the pressurised spacesuit.

Fingertip controllers for direction were on the end of the long 'arms'. The length of these was adjustable to fit astronauts of different sizes.

MANNED MANEUVERING UNIT

WHEN	1984
HOW HEAVY	148 KG (WITH FUEL)
TOP SPEED	87.84 KM/H

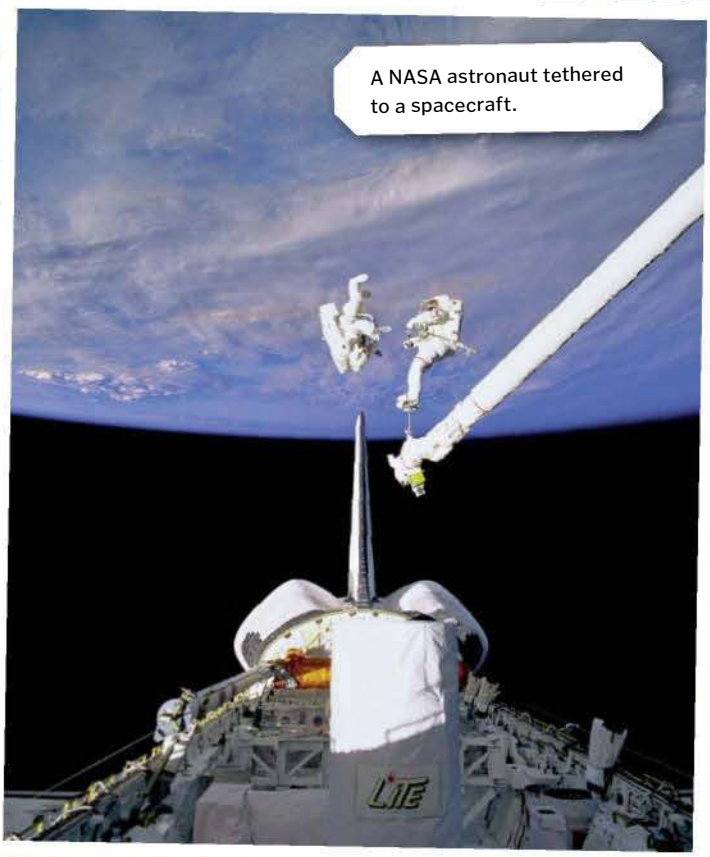
PIGGY-BACK PACK

The MMUs were stored on the wall near the airlock hatch, with the arms folded down. The astronaut had to back into the unit. When the life-support system snapped into place, the arms folded down.

MOVING IN SPACE

On Earth, a person or vehicle has to move against gravity, air resistance and friction against a surface.

In space, none of these constrains movement. Even a tiny force can move something a long way – the gravitational pull of the Earth, or pushing against something, can make an astronaut drift away. To prevent this, astronauts can be tethered to the spacecraft or use an MMU.



A NASA astronaut tethered to a spacecraft.

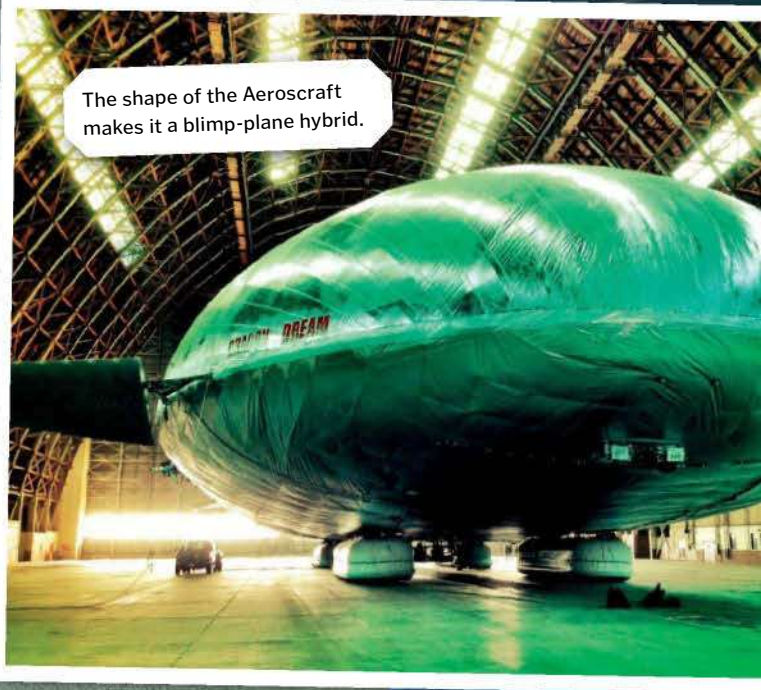
MOST AWE-INSPIRING FUTURE VEHICLES

We've come a long way in the last 150 years. How far will we go in the next 150 years? Here are some of the vehicles that have been suggested or are in development.

A maintenance shaft (with air) is used by staff and in case of emergencies.

A NEW TYPE OF FLIGHT

The Aeroscraft is a giant airship of a completely new type: its lift is provided by both helium (like a blimp) and its shape (like an aeroplane). The largest model will be able to carry 453,000 kg – 500 times as much as the Bullet 580 (see pages 70-71). It could be used for passenger cruises lasting several days. It can take off and land vertically, using six downwards-facing, turbofan jet engines. In the air, it uses electric propellors at the rear to drive it forwards.



The shape of the Aeroscraft makes it a blimp-plane hybrid.

VACUUM TRAIN

A vacuum train (or vactrain) will travel through a sealed tube. If built, it could reach 6,400-8,000 km/h – 2 km per second! That's five to six times the speed of sound, but in the airless tube there would be no sonic boom.

Using tunnels under the oceans, train travel could replace fights between the USA and Europe. It would take less than an hour to get from New York to London. Tubes could also be built on stilts above cities. In China, engineers are working on a first-stage vactrain that could travel at 1,000 km/h.

A vacuum train magnetically levitated from the track travels though a sealed airless tube. There is no air resistance, so the train can go very fast.

If the tunnel is under the sea, it is tethered to huge anchors to keep it in place. Above the surface, stilts are used.

ROBOT CARS

Cars that drive themselves have featured in movies for years. A team at Oxford University has created a prototype car controlled by an iPad. A laser scans the direction of travel 13 times a second. If the car detects an obstacle or a pedestrian, it brakes automatically.

When the car is driven normally along a route, it uses lasers and cameras to scan and 'remember' the route. It can then repeat it automatically. The prototype is a modified Nissan Leaf. The navigation system costs only £5,000 – so the future may not be far away!

It may not look unusual, but this car drives itself!

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